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1935
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BOSTON UNIVERSITY

SCHOOL OF EDUCATION

Thesis

APPRECIATION UNITS IN CHEMISTRY BASED ON PRACTICAL APPLICATIONS IN AN AGRARIAN COMMUNITY AND IN THE HOME

Submitted by

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(A.B., Radcliffe, 1927)

In partial fulfillment of requirements for the degree of Master of Education

1935

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CHAPTER I - DEFINITION OF THE PROBLEM

Within the short space of one hundred years, the teaching of chemistry in the secondary schools has been introduced, developed and constantly changed in its ultimate aim.

Between 1821 and 1830, chemistry came into the secondary curriculum as an elective due to the popular demand of the day. Gerry (21)* said concerning this point: "Chemistry was introduced into the secondary schools to satisfy a popular demand ... The chances to apply chemistry to life were highly regarded by the public but little taught in the schools before the beginning of the 20th century". The presentation of prevailing theory and an encyclopedia of facts were the objectives during the first period of chemical instruction.

Along with other developments in the United States during the middle of the 19th century, the teaching of chemistry progressed but was mainly dominated by the Liebeg method - namely, the automatic performance of simple laboratory work.

During the last half of the 19th century, faculty psychology was rampant. Therefore, chemistry became merely another subject by which mental discipline could be instilled into the young high school students.

In the last decade of the century, the teaching of chemistry assumed its honored post as a preparation for college entrance. Although the aims and objectives of chemical instruction have been revised and redrafted, in many schools today the idea of college preparation still prevails and dominates the method of teaching and content of subject matter.

While commenting upon "some faults of chemistry teaching" Hunter (28)

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*All numbers refer to the bibliography at the end.

writes as follows:

"Texts written show little concerted effort to stimulate thinking or indeed to do more than give factual chemical information and perform laboratory work which is largely mechanical and made to conform with college entrance requirements".

"While we have seen great changes in the content of our courses in introductory science and biological science, chemistry and physics have gone placidly along reflecting the college domination in content and method".

With the turn of the new century, educators began to present opinions that the teaching of chemistry must be reorganized.

Smith (45) said: "We must have unanimity....in regard to the aims and methods of secondary school chemistry and we must work out the detailed organization of the teaching of chemistry more fully".

Woodhull (65) in his conclusion stated: "that the teaching of physics and chemistry in the secondary schools should be less mathematical and more descriptive".

In the report of the Committee on Fundamentals of the Central Association of Science and Mathematics Teachers (19) appeared the following: "The internal organization of chemistry and physics, from the scientific point of view is largely obstruse and mathematical. The strictly scientific approach to them is neither demanded nor allowed by the nature and needs of the high school student".

"There is enough of chemistry in practical life to furnish the necessary concrete entrance to the essentials of the subject".

Sohon (48) presented the idea of teaching in relation to the students and their daily life - "I would give the pupil something to <u>know</u>. Facts that are worth knowing in and of themselves - facts that concern himself, his food, his clothing, his shelter and his work. Concerning the things he or she will meet in life, no matter whether the future be as a chemist,

a bookkeeper or in the kitchen".

Just previous to the outbreak of the World War, many writers presented their opinions concerning the teaching of chemistry and the necessary reorganization of aims and methods.

In 1914 Barber (3) wrote: "One trouble is that the scientific courses in our schools have been directed toward the passage of college examinations rather than to meet the conditions of actual life".

"The high school boy needs to see definitely how the principles learned in his chemistry are related to the burning of the coal in the furnace of which he has charge, to the burning of oil or gas producing the light by which he studies, to his efforts at gardening and agriculture, and to the industries in which his father and older brothers work. The high school girl needs to see clearly how the principles she learns are applied to cooking and cleaning, to dyeing and dietary, to the handling of gasoline and gas stoves, to sanitation rather than to meditation".

"To confine instruction merely to principles of the science, without leading the student to see how these principles are vitally related to the common daily activities of the student and the community in which he lives, is to waste the time of the pupil".

Writing on the function of chemistry, Bray (7) stated: "The more familiar one becomes with the manner in which chemistry is taught in the average high school, the more one is impressed with the idea that there is not a proper appreciation of the real function of elementary chemistry on the part of those who are teaching the subject.... Too often we teach the subject, merely losing sight of the real function of the subject matter in the life of the pupils.... For the pupil the subject has

value and interest in so far as it aids him in the solution of the problems that he meets in his daily life, and in the understanding of the civilization in which he lives".

While pointing out the lack of correlation between chemistry - as taught in the school - to daily life, Hessler (26) stated: "the idea that there is no vital connection between chemistry as taught and as applied in the activities of the home, the farm, the factory, and the community is borne in upon the pupil not only by his own observation, but by the attitude of the school".

In reporting for a 'Committee of a Unified High School Science Course' for the Central Association of Science and Mathematics Teachers, Caldwell (9) said: "They see the need of better unifications in aims and practices in science teaching and better unification in the content of the science courses of the different years of the high school".

In an address in 1915 to the National Education Association, Jones (29) outlined the topics of a chemistry course for girls being given at the Los Angeles High School in which she attempted to relate chemistry teaching to daily life simply by teaching the chemical phenomena occurring daily in the home.

Lewis (33) in 1915 deplored the fact that for twenty years science had been taught in California as a "pure" subject - that is, principles taught without any regard to its practical possibilities. The curriculum was so organized as to leave no time for observation and study of phenomena which should be familiar to the students. He pointed out - "Memorization of the

printed page was all that was required for a high mark. It is needless to point out that this was in no sense science study".

Continuing his work on the need of reorganization, Barber (2) wrote in 1916: "at the present time our classroom instruction must reveal to the high school student something of the story of the discovery of the great truths of science but especially it must make clear to him the monumental effects of applied science upon modern life".

"The beginner in the study of science ... wants to see the go of things; he must first of all be shown the worthwhileness of the task set before him. This can be accomplished only by showing him the significance of science in its applied setting. Out of the applied science, the essential laws and principles may be developed.

"It is our contention that special science in the high school has been a disappointment, not chiefly on account of poorly prepared teachers but chiefly because the selection and organization of subject matter and the methods of approach and development have been fundamentally unpedagogical. The natural interest of the student ... his interest in the applied phases of science as it effects his own personal welfare and the welfare of the community in which he lives".

In 1918 Barber (1) saw the coming of the reorganization of high school science. "The day has passed when it was pertinent to ask whether high school science needs reorganization; high school science is now being reorganized".

"Yet many have been so engrossed in the daily routine of teaching science and have not noticed where science is drifting".

He goes on to plead for a science course based on agriculture and domestic economy - "is it not time that science teachers and high school principals should awaken to a realization of the chaotic condition into

which high school science has been plunged?"

"Still it is inevitable, I believe, that they (school faculties) will treat less of the theoretical aspects of science and more of the practical aspects".

The World War had two effects upon chemistry and the teaching of chemistry - in the first place, chemical industries developed and many new ones came into being. This progress revived popular interest in the study of chemistry. In the second place, the government through the bureau of education saw the need for reorganization of the teaching of chemistry and the formulation of new objectives in keeping with economic and industrial growth of the country.

The Secondary School Circular No. 3 (60) says - "Communities which are not required to make direct contributions to war industries find themselves in need of reorganizing the courses in chemistry in order that they may serve community needs better than is true now. The agricultural, civic, household, and industrial needs, as related to high school chemistry require that chemistry shall incorporate more of the features which touch agriculture, civic life, the home, and the industries".

"Chemistry should be taught by use of a large amount of individual experimental work on the part of teacher and pupil. The information thus gained should be supplemented by readings from up-to-date texts, reference books and technical magazines".

In the report of the committee on the "Reorganization of Science in Secondary Schools" (61) are the following statements: "A course which emphasizes the chemistry of industry, of commerce, of the soil, and of the household furnishes a wider outlook, develops a practical appreciation of the scope of chemical service, and moreover arouses an interest which leads naturally to further study". It goes on to say that "the principal aims in

chemistry teaching are, first, to give an understanding of the significance and importance of chemistry in our national life. The services of chemistry to industry, to medicine, to home life, to agriculture, and to the welfare of the nation, should be understood in an elementary way; and second, to develop those specific interests, habits, and abilities to which all science study should contribute".

The following are opinions of various writers and educators on new aims and objectives for the teaching of chemistry in the secondary schools:

Wirich (64): "Our opportunity to adapt chemistry to social needs, that is, to the needs of each person in society, is such as no one before our time has had".

Snedden (47): "The first type of course should have as its primary purpose "culture" in the sense of interests and appreciations. It should be designed primarily for those who will probably not encounter needs of giving application to chemical knowledge and technique except as utilizers".

"The second type of course should be for those who expect later to apply in some sort of productive process their chemical knowledge and training. Courses of this character should, manifestly, be rigorous, exacting and systematic".

Foster (16): "We need it seems to me, first a revaluation and reorganization of the subject matter of elementary chemistry, and second, a careful revision of our technique of teaching".

Stone (51):..."a start has been made in the right direction in giving to boys not desiring a college preparation an opportunity to make a close acquaintance with the chemistry of things common to their environment or of large use in the industrial world".

Powers (38): "To give to pupils a broad and genuine appreciation of what the development of chemistry means in modern social, industrial and

and national life".

C.E.Osborne (35): "Take advantage of every day's lesson and drive it home with applications to everyday life, to the home, to commerce, to industry. This is live chemistry".

Gorden (22): "To show the service of chemistry to the home, to health, to medicine, to agriculture, to industry; in a word to show the service of chemistry to the country".

Gattis and Marrs (20): "The immediate aim of chemistry should be to furnish the student with a practical and usable fund of chemical knowledge with which to make an interpretation of the daily occurrences that surround him.... An attempt should be made to bring to the student an appreciation of the part played by chemistry in its service to life and civilization .... it is essential that the work of the course be brought as closely as possible into relation with the things of daily life".

Coulson (11): "Give an idea of the importance and significance of chemistry in our national life - give information of definite service to home and daily life".

"The educational aims in teaching beginning with chemistry should be such that they lead to: (1) the appreciation of and respect for the services of chemistry to industry. (2) citizenship through rendering an appreciation of the science in advancing the welfare of society. (3) Excitement of activities relating to better ideals connected with modern home life".

Smith (46): "The immediate aim of chemistry should be to furnish the student with a practical and usable fund of chemical knowledge with which to make an interpretation of the daily occurrences that surround him ... An attempt should be made to bring to the student an appreciation of the part played by chemistry in its service to life and civilization".

Guild (24): "Chemistry touches the life of every person. Chemistry

has so many applications to the life of the average person that knowing what it is and what it does is of more importance than just exactly how to do it ... in the teaching of the subject, in order to give it its correct social emphasis, which is after all the truest criterion of its worth, it is necessary for the teacher to carefully evaluate the content of the course of study and put the proper emphasis on those phases of it that will best adapt themselves to the nature of the individual and his needs in the society in which he lives ... Only enough of the fundamental processes should be included to make intelligible the things that the student will learn about".

The words of the above mentioned writers can be summed up as follows: The aim of the teaching of chemistry is mainly to develop for the students an appreciation and understanding of chemical phenomena in relation to daily life and surroundings.

Then, if we wish to develop an appreciation, one should apply the "appreciation method" of teaching to the greatest extent.

The consensus of opinion is that chemistry teaching has been reorganized, yet this is not true of many school systems.

Segerblom (41) states: "The college entrance examination board wields a strong hand in determining what shall be taught in high school chemistry".

While R.Y.Osborne (36) says: "Science teachers ... agree that extensive reorganization is necessary if the science work of the high school is to be brought into tune with the principles of progressive education".

In turn Sampey (39) writes: "In chemical education ... we are still following traditional <u>purposes</u> even if our methods and subject matter are clothed in modern dress. In a word, we are trying today to make chemists out of the rank and file of our students when we ought to realize that the new responsibility brought on by the creative age in which we live is a

challenge for us to give to the mass of our students a cultural appreciation of the science which is contributing so much to the progress of our time".

Lamont (31) thinks we should teach for immediate use and not just for facts.

Sheean (42) believes we should get away from the teaching of chemistry for discipline to the teaching of chemistry for interest.

While Lake (30) expresses the belief that through the sciences we may develop economic understanding.

More and more, scientific and educational writers foster the opinion that the main aim in the teaching of chemistry is to develop an appreciation of the place of chemistry in every day life in the community, the home, and industry.

G. V. Bruce (8) in the conclusion of his study states, "The Unit method of chemistry teaching is considerably superior to the daily assignment in practical application and appreciation of chemistry in its relation to industry, to the home and to life".

Bateman (4) more recently says, "Many high school instructors are beginning to reorganize their work, so as to instill worthwhile interest and effort in the students. One of the most important trend in science teaching is the increased use of visual methods".

Le Vesconte (32) in an attempt to point out failings of general chemistry teaching for girls states, "Through the maze of formulas, equations and problems, they (i.e. girls) do not see the application in their daily life". She goes on to say that in order to arouse the girls' interest teachers should employ home incidents to illustrate chemical principals and phenomena. Which all reverts to the school of thought that subject matter should be within the pupil's experience.

Many of the newer syllabuses on the teaching of chemistry in the secon-

dary schools record as their primary aim, the development of an understanding of the important role chemistry plays in everyday life.

The Superintendent's Bulletin (52) for the Oakland Public Schools states its objective in teaching chemistry as: "To develop an appreciation of the importance of chemistry to the community and nation. ... The student should be made to see the application of chemistry in his everyday activities, in the preparation of his food, in the protection of his health, in the providing of special comforts and conveniences, in the progress of agriculture and the industries, and in the preservation of the state".

While the Board of Public Education of Pittsburgh, Pa. (6) sets down as its aim: "To point out some of the practical applications of chemistry in daily life.... To provide an opportunity for the pupil to broach his appreciation and understanding of the world in which he lives".

The following figures show that although enrollment in secondary schools has greatly increased, proportionally the enrollment in courses of chemistry has reached an approximately stationary level:

Statistics on Public High Schools - 1927-1928**

Students enrolled in chemistry since 1890

Year	Total No. of Students in Schools Reporting Studies	Students enrolled in Chemistry	Percent of total
1890	202,963	20,503	10.10
1895	350,099	32,020	9.15
1900	519,251	40,084	7.72
1905	679,702	45,980	6,76
1910	739,143*	50,923	6.89
1915	1,165,495	86,031	7.38
1922	2,155,460	159,413	7.40
1928	2,896,630	204,694	7.07

**(Ed. Bulletin 1929 No.35 - page 101 - Table 59)

*Beginning with 1910, the percentages of pupils in each study is based upon the number in the schools reporting studies. In previous years, the percentages were based upon the total number of pupils in all schools reporting.

Statistics on Private High Schools and Academies 1927-1928**

Students enrolled in chemistry since 1890

Year	Total No. of Students in Schools Reporting Studies	Students enrolled in Chemistry	Percent of Total
1890	94,931	8,162	8.6
1895	118,347	11,583	9.8
1900	110,797	10,347	9.3
1905	107,207	9,434	8.8
1910	78,510*	7,367	9.4
1915	125,692	12,485	9.9
1922	180,163	17,348	9.6
1928	248,015	25,326	10.2

**(Ed. Bulletin 1929 No. 19 - Page 16, Table 10)

Hunter (28) gives the following figures to show that chemistry (as generally taught) has apparently failed to reach the students, since the enrollment in chemistry classes has not kept pace with the large increasing enrollment in secondary schools.

Science Enrollment in N.Y. State High Schools

Hunter, - "Science Teaching" - Page 47

Year	Total Enrollment of Secondary Schools	Schools Teaching Chemistry	Enrollment in Chemistry	Percent
1926	353,739	408	24,668	6.97
1927	381,534	422	24,266	6.36
1928	412,213	457	28,192	6.83
1929	434,079	455	30,127	6.36
1930	471,057	490	31,896	6.77
1931	500,664	526	37,797	7.54

I have tried so far to show that the teaching of chemistry has been reorganized in some places and needs to be in others. Yet, many text books (even those which boast new names) still present material inadequate to develop a true appreciation of present day chemistry.

*Beginning with 1910, the percentages of pupils in each study is based upon the number in the schools reporting studies. In previous years, the percentages were based upon the total number of pupils in all schools reporting.

Sampson (40) in his thesis has formulated units in chemistry based on local industries. I propose to set up units in chemistry which will meet the interests and immediate experiences of boys and girls in an agrarian community.

In conclusion, one may deduct from the opinions of the various writers presented in this introduction and from the figures complied by the United States Bureau of Education that the teaching of elementary chemistry has failed to reach its main goal - namely, to develop an understanding and appreciation of chemical phenomena; and to create an appreciation of the immediate relationship chemistry bears to life, home and country.

Since it is impossible, in this paper, to adequately cover the vast field of chemical phenomena, facts and data available to the modern chemist, it seems advisable to indicate only a few points (in each unit) whereby the worthwhileness of chemistry may be stressed to motivate the interest of the students so that they may fully acquire an appreciation of the function of chemistry in life.

More specific limitations are indicated in Chapter II of this paper, but the reader should bear in mind that no unit is a complete treatise in itself. Some chemical phenomena will be partially explained, while others will merely be mentioned, as the writer believes that complete chemical explanations are easily accessible in most textbooks available to teachers of chemistry.

Each unit is presented by the writer of this paper to serve as suggestive material for teachers of elementary chemistry. Naturally each individual teacher will find it necessary to outline each unit of work so as to meet the needs of the specific community, class, and group of students.

1. The Units developed in this paper as teaching units in chemistry are primarily being adapted to the interests of boys and girls living in an agrarian community.

2. The Units included in this paper are not intended to be complete either in number or in length. Time and space will not permit such a treatment. However, the units are offered as suggestions to teachers of chemistry of the type of material that can be included in a course of study in order that students may acquire a better understanding and appreciation of the application of chemistry to everyday life.

3. Equations and symbols are not necessarily needed in an appreciation course in chemistry. Symbolization, valence, laws, etc., are working tools for the professional chemist. Therefore, the elementary student should not be expected to memorize them as such but only consider them in association with the topic being considered.

Twiss (59, p.362) states: "It has been contended that a very valuable course in chemistry can be given without cramming the pupils with symbols and theories.... Yet the habit of emphasizing chemical theory has become so strongly fixed in this country that comparatively few teachers will have the disposition to give a course without considerable of it".

4. This paper will not meet the needs of students who expect to become chemists in future life, but it should arouse their interest in chemistry. Many boys and girls have failed to acquire an understanding of the true scope of chemistry - its relation to daily life, to medicine, to agriculture, and to industry because the method of teaching and the material presented were primarily intended to develop a scientific basis for the professional research chemist. The professionalist should acquire his scientific chemical theory in college; while the secondary school student

should be given the opportunity to acquire the true appreciation of the service of chemistry to the world.

Howe and Turner (27, p.10) write as follows: "The training in chemistry given in our high schools and colleges is unfortunately seldom such as to interest the student in the science as a department of culture and as the all-important handmaid of civilization. No distinction is made between the student who wants to know chemistry, as a chemist should know it, and the student who merely wants to know about chemistry, as any man or woman of broad culture should know about it".

"Most of the text-books have been written as if the object were to exclude every trace of human interest and to make the subject as dry, pedantic, and difficult as possible. As a matter of fact, the whole history of chemistry is replete with romance, from the days of the mediaeval alchemists who vainly sought to transmute lead and iron to gold and to discover the secret of perpetual life, on down to the modern miracles of chemical industry".

"Picture the difference that would result if our general students were shown the dependence of progress in medicine on chemistry; the interrelation of chemistry with all the industries and all the industrial arts; its overwhelming importance in warfares and consequent influence on international relations; its fundamental bearing even upon the thinking of men, not to mention its contributions to transportation, agriculture, mining, and the conservation of natural resources, such as our forests, coal and oil"!

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Water is without doubt the most commonly known chemical compound. It might be well, therefore, to begin a first course in chemistry with the study of water, its relation and significance to our daily lives.

First of all, water is most necessary for each individual's well being. Without water, man can subsist for only a very few days. We use water for drinking purposes; for hygienic and sanitary reasons; for cooking, etc.

Secondly, water is necessary for the proper care and growth of farm animals and plants. Without water, for any length of time, there can be no life - whether that be plant, animal or human life.

In an agrarian community, a child can be led to see that water is a necessity in the home, on the farm and for the individual. In the home, water has many varied uses - for example: cooking and washing; on the farm, water is most essential for the care of farm animals - such as horses, chickens, cows, etc., as well as being most essential for the productivity of the soil; while for the individual, a supply of water is prerequisite for his mental as well as his physical health.

Nature, usually, has provided for the needs of man. For our supply, we draw from surface waters - as rivers, lakes, rainfalls, or seas; from underground waters - as springs and wells; from foods and plants; and from the atmosphere.

In a rural district, the primary problem in connection with water is based upon an adequate supply of water for the soil. Water is absolutely essential for the production of plant growth.

On page 301 of The World Almanac of 1932 (55) are found the following

figures on the amount of water essential for the natural growth and ripening of certain plants:

For every pound grown	Pounds of water consumed
wheat	1,044
barley	831
oats	745
sunflowers	386
corn	227
potatoes	263

(by S. Barnes - Canadian Experiment Station)
(Swift Current, Saskatchewan)

While Thatcher (53, p.15) states: "The actual quantity of water required by farm crops for their successful production has been found to vary from about 250 pounds of water for each pound of dry matter produced, in the case of some of the hardy "dry-land" cereals to as much as 1200 pounds of water per pound of dry matter produced, in the case of some of the succulent forage crops of the humid regions. But in every case, the minimum water requirement of each particular crop must be available in the soil during the growing season if that crop is to develop to full maturity".

Fortunately, in many agricultural regions, nature supplies the needs of the soil. On the other hand, in communities where the rainfall is not sufficient for the soil, man aids nature by applying the process of irrigation. Agriculture in the United States has been widely extended through irrigation. The following figures (taken from p. 358 of the World Almanac of 1935) show with what magnitude it has been applied:

IRRIGATION OF AGRICULTURAL LANDS IN UNITED STATES - 1930

State	Acres Under Irrigation	Capital Invested
Arizona	575,590	$ 73,328,000
Arkansas	151,787	6,836,000
California	4,746,632	450,967,000
Colorado	3,393,619	87,603,000
Idaho	2,181,250	84,500,000
Kansas	71,290	1,685,000
Louisiana	450,901	15,744,000

(cont'd)

IRRIGATION OF AGRICULTURAL LANDS IN UNITED STATES 1930 (Cont'd)

State	Acres Under Irrigation	Capital Invested
Montana	1,594,912	$ 50,319,000
Nebraska	532,617	21,386,000
Nevada	486,648	15,457,000
New Mexico	527,033	19,834,000
No. Dakota	9,392	1,267,000
Oklahoma	1,573	160,000
Oregon	898,713	38,754,000
So. Dakota	67,107	4,502,000
Texas	798,817	49,022,000
Utah	1,324,125	35,669,000
Washington	499,283	40,561,000
Wyoming	1,236,155	35,153,000
Total in U.S.	19,547,544	$1,032,755,000

Thatcher (53, p.16) says: "Crop production with skillful use of irrigation water is a most satisfactory agricultural practice, since in such a case the limiting factor in crop yields is largely under the control of the farmer himself".

More recently another aid to nature is seen in the Roosevelt Reforestation Plan. The proposed tree belt will begin at the Canadian line, run southward through the middle of North Dakota, South Dakota, Nebraska, Kansas, Western Oklahoma into the Texas Panhandle. The theory, as stated in the Literary Digest (33A), is that "it will serve to break the wind, conserve the moisture that happens to fall in the area and perhaps even increase rainfall ... trees certainly do conserve moisture and in this way they tend to raise the water table and otherwise improve conditions".

"The general idea is to spread the benefit over a wide area and if possible give permanent relief from drought throughout the Middle West. If the surface velocity of the wind can be broken even only slightly, soil now subject to wind erosion will remain in place".

Water, since it is a good solvent, is not found pure in its natural state but contains many impurities. The impurities are as follows:

(1) dissolved matter - common salt in sea water; air; carbon dioxide; calcium salts; plant, animal and sewage wastes; oxygen; nitrogen

(2) Suspended matter - mud, sand, clay and dust

(3) Bacteria - especially typhoid and cholera

Large amounts of water are utilized for drinking purposes by both man and animal. Since bacteria is dangerous to human and animal life, the drinking water must be purified.

The purification of water may be accomplished by various methods dependant upon the source of the water supply and its ultimate consumption. Naturally, the teacher will emphasize the particular method being used in the local community, since that problem is alive and will be of immediate interest to the pupils.

Methods of Purification:

1. In the home - (a) faucet filters (not very dependable)
   (b) boiling

2. In the laboratory - distillation

3. Municipal or local supply - (a) settling or sedimentation
   (b) filtering or sand beds
   (c) treatment with chemicals

The water supply, on the farm, must be protected from sewage disposal not only as a protection for humans, but also for the animals - especially the cows, which must be kept free from typhoid infection. In the United States, the spread of contagious diseases has been greatly prevented through the chemical purification of urban and rural water supplies.

During the cold weather, the lakes, ponds and rivers very frequently freeze over. Since children are familiar with these phenomena, a teacher may easily develop changes in state of matter. With a large decrease in temperature, the liquid water has formed into solid ice, yet the composition of water has not changed.

Boys and girls may observe that water has many uses in the kitchen,

and that it may take many forms. For example, on boiling water it evaporates, but later condenses upon the cover of the pan or upon the window panes. Thus, the liquid water passes into the gas steam then it reverts to its original form upon condensation.

Or, they may observe that whenever some water comes in contact with soap, a scum results and may hinder the process of washing. The so-called scum is actually the precipitation, by the soap, of calcium or magnesium salts of fatty acids.

$$2\ C_{17}H_{35}COONa + MgSO_4 \rightarrow (C_{17}H_{35}COO)_2Mg + Na_2SO_4$$

Water containing Magnesium or calcium sulfate is designated as permanently hard; while water containing magnesium and calcium bicarbonates is said to be temporarily hard.

The teacher may find many other vital connections between the chemistry of water and daily life in a rural community.

By association with the environment of the students, the teacher may show the chemical and physical reactions, importance and service of water to the community.

In this unit on water, the following chemical theories and phenomena may be presented through association with things familiar or vital to the everyday environment of the students:

1. Changes of state (liquid, solid and gaseous)
2. Freezing, melting and boiling points
3. Centigrade and Fahrenheit Scales
4. Evaporation, condensation, vaporization, distillation and aeration
5. Solutions, Colloids, Suspensions
6. Temporary and permanent hardness (Methods for softening water)
7. Mechanical and chemical purification

Ref: <u>Black and Conant</u> - "Practical Chemistry"
(revised - Macmillan Co.,1927)

Sections - 11, 46, 48, 49, 50, 51-6, 194-196, 199, 201, 397

Ref: Greer and Bennett - "Chemistry" (Allyn and Bacon,1926)
pp. 25-28, 38-48, 57-58, 62-69, 415-419

Newell, L. C. - - - "A Brief Course in Chemistry" (D.C.Heath and Co.,) 1929)
Sections - 79-84, 87-9, 93, 96-9, 290, 298, 351-2

Excursion

In conjunction with this unit, a visit to the local water purification station is advisable since the boys and girls may thereby see and watch the purification of the very water which he or she drinks.

Educational Films

In addition, the use of educational films helps to make the subject real to the students. There are many good scientific films available now and, these are excellent aids to teaching.

For example, the Eastman Kodak Company has such films as:

1. "The Water Cycle"
2. "Purifying Water"
3. "The New York Water Supply"
4. "Sewage Disposal"
5. "Irrigation"

Supplementary Reading References

Another aid in teaching chemistry is found in popular reading material - through reading, a teacher can develop greater interest in general reading and scientific developments, as well as make adjustments for individual differences. Below, I list just a few sample readings on the subject of water:

1. Chamberlain, J. S. - "Chemistry in Agriculture" (The Chemical Foundation - 1927)

   Importance of soil moisture in plant nutrition - R. W. Thatcher - pp. 14-16

2. Ehrenfeld, Louis - "The Story of Common Things" (Menton, Balch and Company - 1932)

   Chemistry and Health - pp. 99-109

3. Faber, B. W. - "Running Water Service For the Farm"

The Electric Journal 27:392-394 - July 1930

4. Foster, William - "The Romance of Chemistry" (Century Company - 1927)

The Purification of National Waters - pp. 103-108

5. Holmes and Mattern - "Elements of Chemistry" (Macmillan Company - 1927)

Natural Waters and Purification - pp. 60-63 (good pictures)

6. Howe, H. E. - "Chemistry in the World's Work" (D. Van Nostrand Company - 1929)

Health and Sanitation - pp. 145-161 (for more advance pupils)

7. Howe and Turner - "Chemistry and the Home" (C. Scribner's Sons - 1927)

Science in cleanliness (chemistry in the laundry)pp.92-113

8. Kilduffe, Robert A. - "The Old Oaken Bucket May be Full of Germs"

Hygeia - 8:709-12 - August 1930

9. Meister, M. - "Living in a World of Science" - Water and Air (C. Scribner's Sons - 1930)

(a) Water is a necessity in home life - pp. 6-8
(b) " " " " city " - pp. 8-10
(c) " " " " for plant, animal and human life - pp. 11-13

(d) " supplies - pp. 17-33
(e) The forms of water - pp. 67-76

10. Slosson, E. E. - "Keeping up with Science" (Harcourt, Brace and Company - 1924)

(a) Unconscious Sanitation - pp. 76-77
(b) We want water - pp. 118-121
(c) Boiling water and the weather pp. 198-201
(d) Relationship of drinking water with iodine and goiter - pp. 252-56

11. Steel, E. W. - "Impurities of Water"

Hygeia - 7:152-4 (February 1929)

12. Stieglitz, J. - "Chemistry in Medicine"
(The Chemical Foundation - 1928)

Safeguarding the water we drink - J.F.Norton pp.323-339
The scientific disposal of sewage - J.A.Wilson pp.358-373

13. Taylor, C.Stanley - "City Conveniences for Country Homes"

Water supply and sanitary systems

Country Life - 56:70-76 - July 1929

14. Whipple, G. C. - "Pure Water - best of all Drinks"

Hygeia - 9:135-9 (February 1931)

15. "How Nature Purifies Water"

Literary Digest 105:35 (April 25, 1930)

Optional Laboratory Work

The laboratory work in chemistry must be related to the class room work but, at the same time, it must have a definite interest for the pupil and his daily life.

Laboratory work such as listed below will serve to relate school learning with life outside of school.

1. Testing hard and soft water with a soap solution
2. Distillation of a salt solution
3. Filtration of muddy water
4. The formation of dilute, concentrated, saturated and super-saturated solutions of salt and water or sugar and water.
5. Find the water content of vegetable leaves, tomatoes, bits of meat, etc.
6. Making a copper sulphate lead "necklace" from a copper sulphate ($CuSO_4$) solution

It is hoped that at the completion of the study on water, the students shall have obtained an understanding of the service of water and its relation to the individual and his environment.

In the study of water, we noted that neither plant nor animal life can last very long without a replenished supply of water. It is also true that no plant or animal can exist without a sufficient amount of air.

"Air", says Phelps (37, p.101), "is the most intimate and least dispensable part of man's environment. It presses closely against all the external surfaces of the body and forces its way into the lungs, where it freely bathes a large internal surface ... It is not surprising, therefore, to find that health and comfort are dependent in considerable measure upon the atmospheric conditions".

Why is it that without air, we, as human beings, suffocate? What causes animals to drown in water while fishes exist in it? Again, why will neither coal nor wood burn in an insufficient supply of air?

How does hoeing help plants to grow? Why do we protect our buildings and farm equipment from the atmosphere?

Questions similar to the above mentioned will arouse the students' interest in the atmosphere and wherein it affects the individual, the farm and the home.

The atmosphere, a simple mixture of gases - very easily accessible and very abundant - is yet a vital need and foundation of life. Nature, through the atmosphere, uses several chemical processes to maintain plant, animal and human life cycles.

The atmosphere is a mixture of nitrogen, oxygen, argon, carbon dioxide and some rare gases. The Encyclopaedia Britannica (15) gives the composition of the atmosphere as follows:

(see chart on next page)

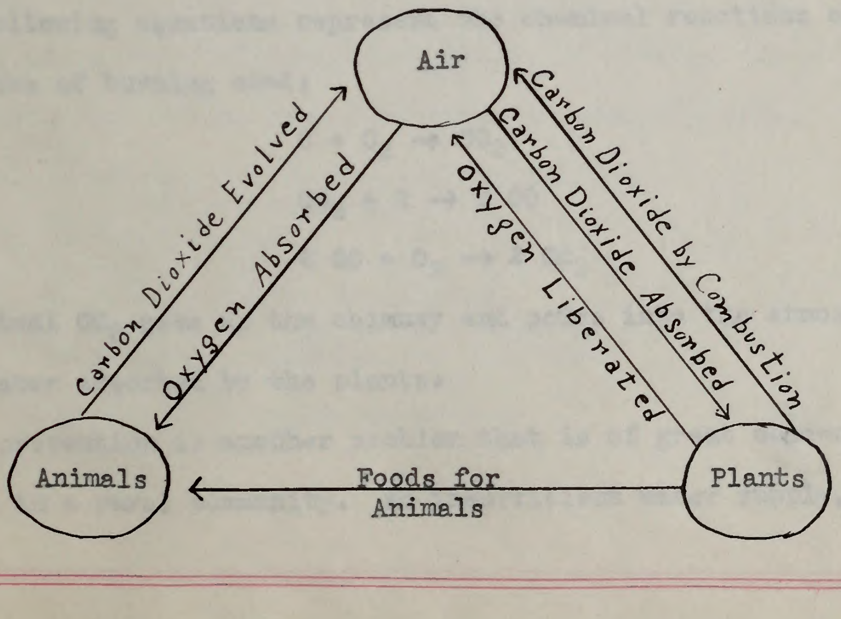
Substance	Volume percent in dry air
Nitrogen	78.03
Oxygen	20.99
Argon	0.93+
Carbon dioxide	0.03
Hydrogen	0.01
Helium, neon, krypton, ozone and xenon	traces
Dry air	100.00

Although nitrogen forms the largest portion of the atmosphere neither plants nor animals are able to utilize it directly. The next abundant element in the air, namely oxygen, is the basic force of all animal life. While the amount of carbon dioxide in the air is very small, it plays a most important part in plant life. The carbon dioxide - a by-product resulting from the burning of coal and other fuels - enters the atmosphere as part of the smoke emitted from chimneys.

Nature, the perfect organizer, has created a balance between the needs of animals and those of plants.

Animals absorb the oxygen from the atmosphere and through the process of breathing exhale carbon dioxide (CO_2). On the other hand, plants absorb the carbon dioxide (CO_2) and liberate oxygen in the presence of sunlight.

The Cycle of Carbon and Oxygen
(page 83 - Black and Conant)



On the farm, the students may notice that plants grow better after hoeing. Greer and Bennett (23, p.107) state: "Hoeing or other methods of cultivation break up the soil so that air comes in contact with the root-hairs of a plant. The root-hairs are then able to absorb water and oxygen from the air. Aeration of the roots of plants is an important process in agriculture. Soil is best for plant growth when it is: (a) loose enough to permit air and water to get at the roots; (b) compact enough to prevent excessive evaporation of water".

"In the winter time, when perennial plants, shrubs, and trees are stripped of their leaves, they are not active. They keep alive but do not grow. At such a time, they retain their vitality chiefly by using the oxygen already in their tissues".

Undoubtedly, at some time, the boy or girl has watched mother or father set and light the kitchen or furnace fire. Why is the paper placed first, then the wood and the coal at last? Again, what is the need for dampers? What happens if they are improperly adjusted? From this point, the teacher may develop the need of air for the economical and safe-burning of coal; the production of carbon dioxide and carbon monoxide; and carbon monoxide poisoning and its affect upon the blood stream.

The following equations represent the chemical reactions occurring in the processes of burning coal:

$$C + O_2 \rightarrow CO_2$$

$$CO_2 + C \rightarrow 2\ CO$$

$$2\ CO + O_2 \rightarrow 2\ CO_2$$

The final CO_2 goes up the chimney and pours into the atmosphere, and is later absorbed by the plants.

Fire prevention is another problem that is of great concern to the individual in a rural community. An insufficient water supply, great

distances and lack of ample fire apparatus may be factors which have generally made rural communities more conscious of the grave dangers of fires.

Combustion, oxidation and methods for extinguishing fires are phases of chemistry that will be of immediate interest to boys and girls in an agrarian district.

Methods for extinguising fires:

1. cooling of the combustible material below its kindling point with water

2. excluding the air so that the supply of oxygen is completely shut off

Examples:

clothing	wrap with a blanket
gasoline	use sand and gravel
oil (small amount)	" " or flour
oil (large amount)	" firefoam (CO_2 foam)

Children may also be interested in the chemical principle of the carbon dioxide fire extinguisher which may be in evidence in one or several places in the school building, and again they may wish to know how the pyrene extinguisher works which father may have attached to his farm truck.

Students of chemistry may obtain an appreciation of the role of the atmosphere to their individual needs and to the needs of their immediate surroundings.

In this unit, the following fundamentals of chemistry may easily be set forth with problems arising from the students' everyday life:

1. Oxidation - normal and spontaneous
2. Speed of oxidation
3. Kindling point
4. Carbon dioxide - oxygen cycle
5. Nascent oxygen and oxides
6. Chemical and physical changes
7. Elements, mixtures and compounds
8. Photosynthesis - catalyst
9. Law of Multiple Proportions
10. " " Conservation of Matter

Ref: Black and Conant - "Practical Chemistry"
Sections 20-32, 60-71, 80, 84-89, 369

Greer and Bennett - "Chemistry"
pp. 15-19, 28-29, 31-36, 81-110, 114-121, 410-412, 424-428, 617

Newell, L. C. - - - "Brief Course in Chemistry"
Sections 9, 10-13, 16, 20-36, 54-65, 143-154, 237

Eastman Kodak Films

1. "Breathing"
2. "Life Saving and Resuscitation"
3. "Fire Making"
4. "Fire Prevention"
5. "Fire Protection"
6. "Fire Safety"
7. "The Green Plant"

The Boston University School of Education maintains a free film service, whereby schools may obtain the loan of educational films. For this unit, the following films may be used:

1. "Carbon Monoxide, the Unseen Danger"
2. "Fire Prevention"

Supplementary Reading References

1. Chamberlain, J. S. - "Chemistry in Agriculture"
The Plant in Air and Light - J. M. Arthur and H. W. Papp
pp. 18-51

2. Darrow, Floyd L. - "The Story of Chemistry"
(Bobbs-Merrill Co. - 1930)
After the Alchemist - p. 14-25
(more advanced)

3. Foster, William - "The Romance of Chemistry"
The Atmosphere and Oxygen - pp. 58-78
Carbon Dioxide and the Cycle of Carbon - pp. 352-357
Carbon Monoxide - pp. 357-359
Photosynthesis - pp. 384-388

4. Hale, Wm. J. - "The Farm Chemurgic"
(The Stratford Co. - 1934)
The Four Horsemen - pp. 57-76
(more advanced)

5. Harrow, Benjamin - "The Making of Chemistry"
(John Day Co. - 1930)
Priestley and Oxygen - pp. 37-42
Lavoisier - pp. 43-52

6. Holmes and Mattern - "Elements of Chemistry"
   Oxygen and Ozone - pp. 19-33
   Oxides of Carbon and Uses - pp. 258-263
   Cycle of Carbon in Nature - pp. 263-269

7. Meister, M. - "Living in a World of Science" - Water and Air
   Air - pp. 88-100
   Air and Life - pp. 104-113
   The Airplane - pp. 159-180

8. Slosson, E. E. - "Keeping up with Science"
   Food from the Air - pp. 69-71
   Two Kinds of Conservation - pp. 191-192
   How Seeds Breathe - pp. 269-272

9. Stieglitz, J. - "Chemistry in Medicine"
   The Need of Air - Earle B. Phelps - pp. 101-111

10. Tower and Lunt - "The Science of Common Things"
    (D. C. Heath and Co. - 1922)
    How to Supply our Homes with Fresh Air - pp. 14-16
    Facts Everyone Should Know About Air - pp. 17-22

Optional Laboratory Work

1. Analysis of samples of indoor and outdoor air
2. Construction of a balanced aquarium
3. Test for CO_2 in the breath
4. Test green leaves and dry leaves for oxygen

The result of the study of this unit on the atmosphere, is expected to create an appreciation of the chemical application in the everyday life situations of the students.

Fertilizers - renewed life for the soil - certainly will serve as a very vital subject to inhabitants of an agrarian community. Upon the fertility of the soil is dependent the entire happiness and economic welfare of the agriculturist and his family.

Why is a farmer greatly concerned with the various types and brands of fertilizers? Since some fertilizers are expensive, why does the agriculturist feel that regardless of the cost certain fertilizers are most essential for his land if he expects to have a good crop at harvest time?

A good crop generally denotes a larger financial return for the farmer. Therefore, boys and girls studying chemistry will be interested in what constitutes fertile soil and how to maintain that fertility.

"Growing plants", says Curtis (12, p. 76), "take up from the soil certain socalled mineral foods which are as essential to their growth as sunlight, air and water. A fertile soil must contain a reserve of these substances adequate to the plants' demand, and where crops are removed from the land year after year it is obvious that the soil is being slowly depleted of essential plant foods".

While Greer and Bennett (23, p. 700) state: "Soils contain several elements which plants must have for their growth. Although all these elements of the soil are needed for the growth of various plants, three of the elements are likely to be lacking in tilled soil. These elements are:

(1) Nitrogen (2) Potassium (3) Phosphorous

In order to make the soil most productive, it is necessary to add these elements to the soil".

On page 302 of the World Almanac of 1933 (56) is shown that in 1929 alone, the farmers of the United States bought $271,058,673 worth of

fertilizers.

Tons of Fertilizer Sold in U. S.
(ton=2000 lbs.)

(from p. 561 - Statistical Abstracts of U. S.)(49)

Year	Tons
1925	7,333,166
1926	7,328,268
1927	6,843,199
1928	7,985,019
1929	8,078,548
1930	8,163,870
1931	6,306,082

Output by Fertilizer Plants in the U. S.

(page 151 - Encyclopaedia Americana)(14)

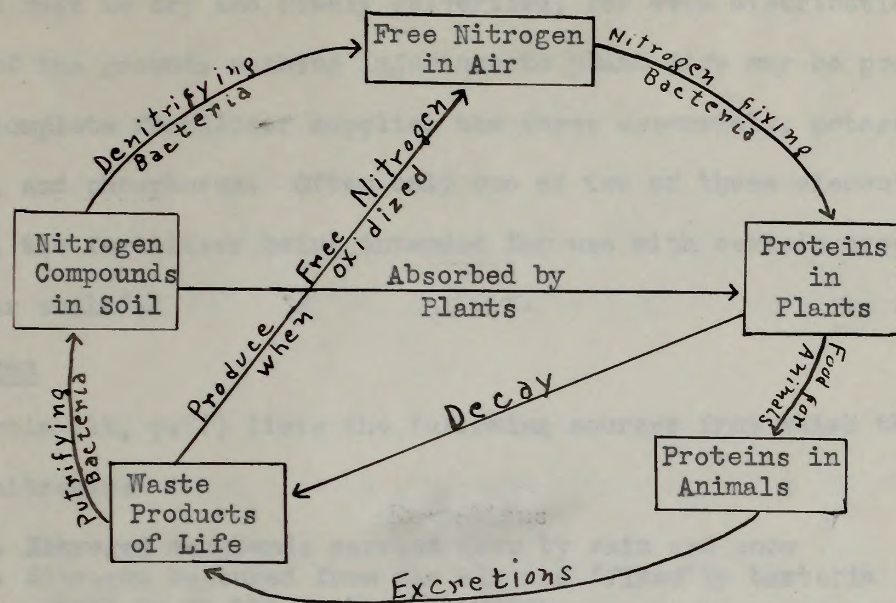
Year	
1859	$ 891,344
1869	5,815,118
1879	23,650,795
1889	39,180,844
1899	44,657,385
1929	219,001,224

On page 538 of the New International Encyclopedia, (54) Supplement (vol. I) is found the following statement: "It is estimated that 7,600,000 tons of commercial fertilizers costing the farmer $249,660,000 was used in the United States in 1928, and this country is far behind European countries in the per-acre consumption of fertilizers".

The student can be shown again, the part nature plays in the relationship of plant life to animal life as exemplified by the nitrogen cycle.

(see chart on next page)

Nitrogen Cycle in Nature
(Black and Conant - p.244)



As noted in Unit II, there exists in the atmosphere nearly 80% of nitrogen, which cannot be assimilated directly by animals. On the other hand, only a few leguminous plants, such as alfalfa, beans, clover and peas, can get atmospheric nitrogen through the medium of nitrogen-fixing bacteria, attached to the roots of their plants which are capable of converting atmospheric nitrogen to nitrogen compounds.

The nitrogen cycle does not continue unimpared in modern-day life because the waste products of plant and animal life, generally, do not go back to the soil; and because certain denitrifying bacteria in the soil convert some of the nitrate compounds into free nitrogen and it is lost in that nascent state. Therefore, the supply of nitrogen in the soil must be replenished by artificial fertilizers containing nitrogenous compounds and by the rotation of crops.

Thorp (58, p.164) writes: "Artificial fertilizers are manurial substances prepared from materials needing special treatment to render them fit for plant food. The chief requisites for a good artificial fertilizer

are: It must contain at least one substance fit for plant food, and which is easily converted by rain or moisture into a form that plants can assimilate; it must be dry and finely pulverized, for even distribution over the surface of the ground; nothing injurious to plant life may be present".

"A complete fertilizer supplies the three essentials, potassium, nitrogen, and phosphorus. Often only one or two of these elements may be afforded, the fertilizer being intended for use with certain crops or on particular soils".

I. Nitrogen

Curtis (12, p.77) lists the following sources from which the soil secures nitrogen:

"1. Nitrogen compounds carried down by rain and snow
2. Nitrogen captured from the air and "fixed" by bacteria living in the soil or on the roots of legumes
3. Animal manure, both that produced by domestic animals and that secured from deposits such as the guano found particularly on islands off the coast of Peru
4. Nitrogenous waste materials such as cottonseed meal, meat packers' scrap, fish scrap, etc.
5. Sodium nitrate from the natural nitrate beds of Chile
6. Ammonium sulphate produced in the coking of coal
7. Nitrogen captured from the air and fixed by chemical processes"

If desired, the teacher may develop the economic need of the nitrogen fixation plant which was set up by the United States Government at Muscle Shoals in the early years of the World War; and its recent conversion into a nitrate plant as part of the T.V.A. development.

Students of a rural district will be interested in Chile saltpeter or "caliche" since Sodium Nitrate ($Na\ NO_3$) is the most important nitrate used as fertilizer. This topic will afford the teacher an opportunity to present the historical and economic importance of the natural nitrate deposits in South America, - for, the monopoly on the nitrate supply has been the cause

of expensive fertilizers in the past and therefore has drained the fertility of the soil and the pockets of the farmers.

II. Potassium

Has the child ever noticed that very often the wood ashes are placed on the soil? The rain water extracts the K_2CO_3, or potash, from the ashes and serves as a source of potassium necessary for plant growth. The good farmer, however, in modern civilization, does not depend upon wood ashes, but supplies the potassium food for the plants as part of his artificially mixed fertilizers.

Greer and Bennett (23, p.703) show that: "With potash a yield of oats was 51 bushels per acre; without potash the yield was 21.5 bushels per acre".

The carnallite deposits at Stassfurt, Germany should not be neglected in a chemistry course of study since they are of economic, chemical, as well as agricultural importance.

III. Lime

Many farms, in the past, have been abandoned for the simple reason that they became "sour" or "acid". The farmer today avoids or corrects the acidity of the soil by the use of ground limestone (Ca CO_3) or lime ($Ca(OH)_2$) and chalk.

"It frequently happens", state Black and Conant (5, p.319): "that soil needs liming because it contains too much acid formed from decomposing vegetable matter. Such crops as grains and grass will not thrive on "sour" soil, and so it is "sweetened" by spreading slaked lime ($Ca(OH)_2$) upon it".

IV. Phosphorus

Phosphorus is one of the constituents of artificial fertilizers. It may be in the form of calcium acid phosphate (or generally as superphosphate of lime). The superphosphate is used since it is water soluble and can be

readily utilized by the plant from the soil.

Black and Conant (5, p. 318) say: "The rock phosphates of Florida, Georgia, Tennessee, and the Carolinas are very largely composed of calcium phosphate ($Ca_3(PO_4)_2$). Since this phosphate is almost insoluble in water, it is converted by the action of sulphuric acid into the calcium dihydrogen phosphate ($Ca\ (H_2PO_4)_2$), which is much more soluble.

$$Ca_3(PO_4)_2 + 2\ H_2SO_4 \rightarrow 2\ CaSO_4 + Ca(H_2PO_4)_2$$

The resulting mixture of calcium sulphate and calcium acid phosphate is known as superphosphate of lime, which is a fertilizer".

If the students should so desire, with the help of the teacher, they may go into the problem of the relative percentages of the different brands of commercial fertilizers, and consider which of these are best suited for the growing of specific crops.

Without doubt the study of fertilizers will create an appreciation of the role of chemistry to agriculture and will be of interest to the pupils since it is closely related to their immediate surroundings.

In this unit, the following chemical data may be developed yet directed to the individual interests of the students:

1. Acidity and basicity
2. Absorption and adsorption
3. Chemical compounds - nitrates, sulphates, chlorides, phosphates and carbonates
4. The process of nitrogen fixation
5. Solubility and insolubility
6. Valence
7. Indicators

Ref: Black and Conant - "Practical Chemistry"
sections - 196, 242-243, 249-251, 255-256, 287-290, 330-331, 336

Greer and Bennett - "Chemistry"
pp. 275, 419-422, 618-619, 623-624, 641-643, 650, 691, 697, 700-703

Newell, - "A Brief Course in Chemistry"
sections - 142-143, 159-161, 196, 200, 202, 287-288, 292, 299-300

Eastman Kodak Educational Films

1. "Cotton Growing"
2. "Denmark"
3. "Puerto Rico" - No. 3 Rural Life
   " 4 Agricultural and Industrial Products
4. "The New South"
5. "Wheat"
6. "Limestone and Marble"
7. "Sand and Clay"
8. "The Formation of Soil"
9. "Corn"
10. "Market Gardening"
11. "Peru"

B. U. School of Education - Film Service

1. "The Care of Grain Seeds"

Excursion

A visit to an agricultural experimentation station (if one is located at a reasonable distance) would prove to be of uttermost importance and interest to the students, since there they may actually see the problems and results of agricultural chemistry.

Supplementary Reading References:

1. Chamberlain, J. S. - "Chemistry in Agriculture"

   Soil Life - Jacob G. Lipman - pp. 52-75
   Where the Nitrogen Comes From - Harry A. Curtis pp. 76-91
   Maintaining Soil Fertility - G. S. Fraps - pp. 92-105
   Fertilizer Control - B. B. Ross - pp. 359-374
   Insecticide Control -" " " - pp. 380-384

2. Darrow, Floyd L. - "The Story of Chemistry"

   Agriculture and War - pp. 213-252

3. Foster, Wm. - "The Romance of Chemistry"

   Nitrogen and Fertilizers - pp. 188-197
   Phosphorus - pp. 204-210
   The Farmer's Dependence on Chemistry - pp. 382-384
   Chemistry and the Soil - p. 388
   Nitrogen,Potassium and Phosphorus as Plant Foods -pp.389-392
   Compost and 'Indirect' Fertilizers - pp. 392-394
   Bacteria on the Farm - pp. 394-399

4. Hale, Wm. J. - "The Farm Chemurgic" (Statford Co. - 1934)

(a) Intense Nationalism - pp. 19-31
(b) Chemical Life Cycles - pp. 77-89
(c) The Wreck of the Farm Cycle - pp. 90-101
(For more advanced pupils)

5. Holmes and Mattern - "Elements of Chemistry"

Nitrogen - pp. 204-205
Nitrogen Fixation - pp. 210-216
Fixation of Nitrogen by Bacteria - pp. 223-225
Phosphate Fertilizers - pp. 240-243
Potassium Salts in Agriculture - p. 390

6. Howe, H. E. - "Chemistry in the World's Work"

Food for Plants - pp. 55-61
Soil Analysis - p. 64

7. Howe and Turner - "Chemistry in the Home"

Chemistry in the Garden - pp. 327-340
Chemistry and Soil - pp. 341-350

8. Lassar-Cohn - "Chemistry in Daily Life" (Lippincott Co. 1913)

Foods of Plants - pp. 36-56

9. Rae, John B. - "The Relation of Chemistry to Agriculture"

J. Chem. Ed. 5:1068-1073 (Sept. 1928)

10. Slosson, E. E. - "Keeping up with Science"

Plant Food from the Air - pp. 69-71
Fixing Nitrogen for Fertilizer - pp. 110-114

11. Slosson, E. E. - "Creative Chemistry"

Nitrogen - preserver and destroyer of Life - pp. 14-36
Feeding the Soil - pp. 37-59

12. Thorp, Frank H. - "Outlines of Industrial Chemistry"
(Macmillan Co. 1925)

Fertilizers - pp. 164-173 (For more advanced pupils)

13. Van Buskirk and Smith - "The Science of Everyday Life"
(Houghton Mifflin Co. 1933)

Plants - Food Makers for the World - pp. 264-280

Optional Laboratory Work

1. Study of samples of local soil
2. Critical examination of several brands of artificial fertilizers on the market.*
3. Test for a nitrate
4. " " " phosphate
5. " " " sulphate
6. " " " carbonate
7. Litmus and phenolphthalein - results with acid and alkaline solutions

The study of fertilizers and the soil is expected to create a clear understanding and appreciation of the meaning of chemistry and its close relationship to scientific farming, as well as being a topic of great interest to the students and related to their environment.

* See Bulletin No. 28, U. S. Department of Agriculture; Division of Chemistry

Fuels are essential to the well being of mankind, the proper care of farm animals and a requisite for the operation of modern farm equipment. Considering these points, the chemistry of fuels will be a vital phase in a course of study for an agrarian community since it concerns the student, his surroundings and his welfare.

What type of heating and lighting facilities are used in the student's home; and in the farm buildings? What are the relative costs of various fuels? Which type of fuel is most economical from the standpoint of actual cost and from the actual heat produced?

These questions and many similar ones may come up in the class discussion since they are alive and pertain to pupils' home life and to the family's financial problems.

The student has doubtless observed, at some time, that soot has been deposited on the bottom of a pan due to the improper functioning of the gas or oil stove burner. What causes the soot and why does it result from both gas and oil burner? The teacher may thereupon open up the study of coal, the numerous types of fuel gases and the refining of petroleum.

<u>Forms of Carbon</u>

Crystalline	Noncrystalline
Diamond	Burnt sugar
Graphite ("Lead" pencils)	Wood charcoal
Hard coal	Coke
	Lampblack
	Carbonblack
	Boneblack

It never fails to interest boys and girls that all the above-mentioned are basically different forms of the same chemical element - namely, carbon.

Form of Carbon	Uses	Property on Which Use is Based
Diamond	Precious stone Cutting glass	Color, brilliance, size, hardness
Graphite	Lubricant Pencils	Soft, flat crystals Soft, leaving black mark
	Paint, ink, stove polish Crucibles and electric-furnace electrodes	Inactive chemically Inactive chemically; has a high melting point
Coke	Fuel and reducing agent	Combustibility and union with oxygen when hot
Wood charcoal	Fuel Reducing agent	Combustibility Ready union with oxygen when hot
	Decolorizer and deodorant	Porosity; adsorption (i.e. ability to take up solids, liquids, and gases)
Bone black	Decolorizer	Adsorption
Lampblack	Paints, inks, shoe polish	Insolubility; inactivity
Carbon black	Paints, inks, gas masks	Insolubility, inactivity, adsorption

(Greer and Bennett - page 404)

The diamond form is hardly associated with the graphite from which our "lead" pencils are made. Certainly the beautiful diamond is rather hard to conceive as the same element as the black coal which we burn to keep us warm in cold weather.

The diamond may not appear to be the same chemical as coal, yet it is the same element and is obtained from similar sources - that is, mine deposits formed by the decomposition of vegetation in the earth's stratum.

I. Fuels

A good coal fire is made by the careful adjustment of the dampers. Without question, the student may have started a coal fire or has probably

watched the processes. The teacher, then, may connect the chemistry involved in the burning of coal and adjustment of the stove dampers.

$$2C + O_2 \rightarrow CO_2 + 96{,}480 \text{ Calories/gm}$$

The warmth we seek from the burning is the heat that is liberated by the burning of coal and is represented in the above equation as Calories or heat value.

There are three classes of fuels - namely, solid, liquid and gaseous.

Solid	Heating Value (Calories/kilo)	Liquid	Heating Value (Calories/kilo)	Gaseous	Heating Value Calories/ cub. meter
Wood	3000-4000	crude petroleum	11,000	Natural gas	9400
Peat	4000-5000			Coal "	
Lignite	4000-6000			Water "	
Bituminous coal	6000-7500				
Anthracite coal	7500-8500				
Charcoal	7100				
Coke	7600-8100				

The student may note that hard coal is burnt in his household while someone else is using soft coal. What are the relative differences in the two kinds and which is the more economical in terms of actual heat liberated?

The advantages and disadvantages of illuminating gas may be compared with the kerosene oil used in the kitchen burner. Or the topic of natural gas (its chief constituent being methane - CH_4) can be introduced if the community is located in the natural gas areas.

The following table taken from page 44 of Thorp (58) shows the chemical composition of some fuel gases:

The Average Composition of Various Fuel Gases

	Percents						
	H_2	CH_4	C_2H_6	CO	CO_2	N_2	O_2
Natural Gas (Pittsburgh)	--	79.2	19.6	--	0.03	1.2	--
Coal Gas	49.8	29.5	3.2	8.5	1.6	3.2	0.4
Water Gas	50.8	0.2	--	40.9	3.4	3.5	0.9
Producer Gas (coal)	10.4	6.3	--	17.6	7.3	58.1	0.7

Kerosene lamps probably are not rare objects to children in rural communities. What causes the lamp chimney to become coated with soot when the wick has been turned up too high? Just as the uncombined carbon (i.e. "soot") was deposited on the bottom of the pan placed on the poorly adjusted gas burner, so has the uncombined carbon settled on the kerosene lamp chimney.

The various types of fuels are obtained from different sources - as indicated below:

Type	Source
Wood	forest lumber
Coal	mine deposits
Wood charcoal	destructive distillation of wood
Coke	" " " coal or a by-product of illuminating gas manufacture
Natural gas	found underground in certain areas
Kerosene	fractional distillation of petroleum oil
Illuminating gas	manufactured from coal
Gasoline - for engine	fractional distillation of petroleum oil
Fuel Oil	refining of petroleum

From the fractional distillation of petroleum we get kerosene (for kerosene stoves and lamps); gasoline (for fuel for the farm truck or family automobile); lubricating oil (for the lubrication of the farm machinery); vaseline (for medicinal usage in the home); paraffin wax (which is used to make the waxed paper and similar products which are used in practically every household and also used in covering jellies); fuel oil (for kitchen oil stoves and oil furnaces) - and tar pitch residue (which is used to make the roofs of homes, school buildings, farm buildings, etc., water proof). The "asphaltic" tar has been employed to make many of the modern roads.

What Comes From a Barrel of Crude Oil
(p. 347 - Black and Conant)

Gasoline	23.3%	Boiling Point $60^\circ - 222^\circ$ C
Kerosene	13.5	$200^\circ - 300^\circ$ C
Fuel Oil	44.6	$250^\circ - 350^\circ$ C
Lubricating Oil	5.0	
Miscellaneous Oil	7.5	
Wax-asphalt	2.3	
Loss	3.9	

Illumination in an agrarian community may be supplied by candles, kerosene lamps, illuminating gas burners, or electricity. The teacher will therefore develop the chemical principles which are involved in whichever type or types are most prevalent in the particular community, thereby meeting the needs and interests of the class.

II. Matches

Most all our stove fires or illuminates are started by matches. What are matches? Why are they necessary conveniences? Matches are common objects in the home and in the school laboratory. It is natural to assume that students will be interested in the chemistry of match making and the past history of the making and development of our modern type of matches.

There are two kinds of matches - common (or strike-anywhere matches) and safety matches. Red phosphorus is used to make the common matches because it has a low kindling point (therefore can be ignited by friction) and is non-poisonous. However, the phosphorus is not used by itself on match heads but is combined with an oxidizing agent (to aid the burning), a glue (to make the mixture adhere to the match stick, and a gritty substance such as ground glass (to increase friction).

Greer and Bennett (23, p.693) write: "When a friction match is struck, several changes occur. The heat generated by rubbing is sufficient to raise the phosphorus to its kindling temperature. It burns and at the same time heats the oxidizing material, which decomposes and furnishes oxygen to hasten the process of burning. The burning phosphorus then heats the paraffin or other inflammable material to its kindling point. This other inflammable material burns and in burning ignites the wood".

In safety matches, the components are both on the match sticks and on the side of the box.

Match Tips	Box
1. Easily oxidizable substances (as Sb_2S_3)	Easily oxidizable substances(as red phosphorus)
2. Oxidizing Agent (as $KClO_3$)	Oxidizing Agent (as MnO_2)
3. Gritty substance (as powdered glass)	Gritty substance (as powdered glass
4. Glue (for adherence)	Glue

The friction produces enough heat to ignite a small bit of red phosphorus which being in contact with the head of the match causes the match to take fire.

Surely the word "safety" will catch the interest of the student. Matches are thus denoted since ignition will take place only when the match is scratched on the part of the box which has been chemically treated.

It is hoped that the chemistry of fuels will bring to the students a better understanding of the connection of chemistry to their daily lives and their immediate surroundings.

In this unit the following chemical phenomena may be presented in association with the pupils' vital interests:

1. Allotropic forms
2. Law of Conservation of Energy
3. Exothermic and endothermic reactions
4. Fractional distillation
5. Flash point
6. Combustible and uncombustible matter
7. Oxidation and reduction
8. Dry or Destructive Distillation

Ref: Black and Conant - "Practical Chemistry"
sections - 334, 342-349, 351-354, 363-366

Greer and Bennett - "Chemistry"
pages - 382-405, 433-437, 451-454, 486-503, 692-694

Newell, L. C. - "A Brief Course in Chemistry"
sections - 231-253, 383-390, 414

Eastman Kodak Educational Films

1. "The Automobile"
2. "Anthracite Coal"
3. "Bituminous Coal"
4. "Lumbering in the Pacific Northwest"
5. "Producing Crude Oil"
6. "Four-stroke Cycle Gas Engine"
7. "Hot Air Heating"
8. "Illumination"
9. "Refining Crude Oil"

B. U. School of Education - Film Service

1. "Automobile Lubrication"
2. "The Story of Gasoline"
3. "Petroleum"
4. "The Story of Lubricating Oil"

Supplementary Reading References:

1. Caldwell and Slosson - "Science Remaking the World"
   Gasoline as a World Power - pp. 12-46
   (For more advanced pupils)

2. Darrow, F. L. - "The Story of Chemistry"
   Chemistry and Power - pp. 152-194
   Illuminating and Fuel Gases - pp. 197-212

3. Foster, Wm. - "Romance of Chemistry"
   Friction Matches - pp. 210-213
   Carbon, Producer of Energy - pp. 341-352

4. Holmes and Mattern - "Elements of Chemistry"
   Matches - p. 237
   Carbon - pp. 248-257
   Fuels - pp. 271-296

5. Harrow, Benj. - "The Making of Chemistry"
   Coal and Petroleum - pp. 164-173

6. Howe, H. E. - "Chemistry in the World's Work"
   Allies of the Sun - pp. 40-54
   Power and Fuels - pp. 162-177

7. Howe and Turner - "Chemistry in the Home"
   Fuels and the future - pp. 314-326
   Illumination - pp. 275-285
   The Flash-light - pp. 289-297

8. Lassar-Cohn - "Chemistry in Daily Life"
   Nature of Flame - pp. 16-35

9. Meister, M. - "Living in a World of Science - Heat and Health"
   Chap. I - Sources of Heat - pp. 1-14
   " II - Fuels and Fire - pp. 15-25
   " III - Uses of Fire - pp. 33-41
   " IV - Extinguishing Fires - pp. 50-52
   " IX - Heating Buildings - pp. 113-125

10. Slosson - "Keeping up with Science"
   An Industry Saved - pp. 74-76
   Two Kinds of Conservation - pp. 188-192
   Climate in the Coal Age - pp. 234-237

11. Thorp, F. H. - "Outlines of Industrial Chemistry"
Fuel - pp. 32-45 (for more advanced pupils)
Matches - pp. 258-259
Illuminating Gas - pp. 312-326
The Petroleum Industry - pp. 334-345
Candles - pp. 380-383

12. Tower and Lunt - "The Science of Common Things"
A Study of Fire - pp. 145-181
How we Heat our Homes - pp. 183-218
How we Light our Homes - pp. 219-258

13. Van Buskirk and Smith - "The Science of Everyday Life"
Heating our Homes - pp. 374-394

Optional Laboratory Work

1. Preparation of charcoal from dry wood
2. Study of the ash residue of different brands of coal (preferably samples from the home supplies)
3. Formation of soot - by candle
   " gas
   " fuel oil
4. Making of carbon paper

At the completion of this unit, it is hoped that the students shall have developed an appreciation of the chemistry of fuels and their service to the individual and the community.

It has been noted in previous units that life is dependent upon water, air and food. Air and water are most important, yet life cannot continue indefinitely without replenishing the supply of food, which forms the source of energy.

In Unit III, facts were presented which showed that plants must have food for their growth, and that the elements of food are obtained from the soil and therefore, the maintenance of soil fertility is of utmost necessity in order to insure proper plant life and growth.

Animals, like plants, need constant energy in order that the body structure may function properly, and thereby sustain animal life.

Human beings supply the energy needs of the body structure by means of consumed food-stuffs. Naturally, therefore, it is plausible to assume that students in chemistry will be interested in the chemical constituents of their daily food, and the specific functions of the different foods.

Foster (17, p.400) writes: "Some of the most valuable contributions of modern chemistry have been made in the field of food and nutrition; and it is now well recognized that a proper diet is closely related to the health and happiness of human beings".

Why is it that most people prefer their bread buttered? Why is milk especially prescribed for children? Chemically, what is nutrition? On the radio, in newspapers and magazines today, much time and space is devoted to balanced meals and diets. What difference does it make what and how we eat? The topic of vitamins appears in many of the American advertisements. What are vitamins and why are they involved in selling campaigns?

During the past months, several of our federal legislators have been considering the revision of the Pure Foods and Drug Act. Why should the

government be concerned with such matters? Why do we feel cold whenever we are extremely hungry? In the summer, why do we eat more vegetables?

Page after page could be taken up with questions (as noted above) which a teacher of chemistry may use to arouse the interest and curiosity of the students on the topic of foods, their importance and relation to the happiness and welfare of the individual.

In the first place, it is found that foods serve human beings in three ways, namely:

1. to build up tissue and replace worn out ones - bodily growth and repair
2. to maintain body temperature
3. to supply the energy needed for work, play, etc.

Chemically, foods are divided into the following classes:

1. Carbohydrates - supplying heat and energy
2. Fats - producing heat and energy
3. Proteins - building and repairing tissues
4. Vitamins - maintaining health and growth
5. Mineral salts - (compounds of Fe, Ca, P and I) - reenforcing bone structure and the blood stream
6. Water
7. Roughage

I. Vitamins

The story and development of all the vitamins known to date will furnish the students in chemistry a slight picture of the part research chemists, everywhere play not only in the further developments in chemistry but just as well in the field of preventative medicine and health.

Vitamin A - growth producing - prevents blindness
" B - antineuritic - promoting appetite
" C - antiscorbutic - preventing scurvy
" D - antirachitic - " rickets
" E - antisterilitic - " sterility

Since vitamin C is destroyed by heat, a proper dietary should include uncooked fresh vegetables and fruits.

Vitamin Values of Some Common Foods
("Chemistry in Agriculture" - page 281)*

Article of Food	Vitamins A	Vitamins B	Vitamins C
Apples..................................	Poor	Poor	Fair
Bananas.................................	Little	Little	Fair
Barley, whole...........................	Poor	Good	Trace
Beans, navy.............................	Unknown	Rich	Trace
Beets...................................	Fair	Fair	Fair
Bread, white (water)....................	Doubtful	Little	Doubtful
Bread, whole wheat (milk)...............	Good	Good	Doubtful
Cabbage, raw............................	Good	Good	Rich
Carrots, fresh raw......................	Good	Good	Fair
Codliver oil............................	Very Rich	Trace?	Trace
Corn, white.............................	Trace	Good	Trace
Corn, yellow............................	Fair	Good	Trace
Cottonseed oil..........................	Little	Trace	Little
Eggs....................................	Good	Fair	Poor
Grapefruit..............................	Unknown	Good	Good
Kidney..................................	Good	Good	Little
Lard....................................	Little	Trace	Trace
Lemon juice.............................	Unknown	Good	Rich
Lettuce.................................	Good	Good	Rich
Liver...................................	Good	Good	Fair
Meat (muscle)...........................	Trace	Little	Little
Milk....................................	Rich	Good	Fair
Oats....................................	Poor	Good	Trace
Orange juice............................	Poor	Good	Rich
Peas, green.............................	Good	Good	Poor?
Potatoes, white, boiled (15 minutes)....	Little	Fair	Fair
Spinach, fresh..........................	Rich	Rich	Good
Tomatoes, raw...........................	Good	Rich	Rich
Tomatoes, canned........................	Good	Rich	Rich
Yeast...................................	Absent	Rich	Absent

II. Composition of Foods

The teacher may now present the chemical components which go to make up each class and the relative chemical changes which they undergo in the processes of digestion.

Harrow (25, p.149) says: "The absence of these vitamins from a diet gives rise to what are known as food deficiency diseases; diseases, in other words, due to one or more specific deficiencies in the diet".

*From Bulletin 184 - Arkansas Agricultural Experiment Station

Substances Composing Foods
(Van Buskirk and Smith - p.223)

Nutrient	Examples	Elements Present
1. Carbohydrates	Starch and sugars	C, H_2 and O_2
2. Fats	Butter, lard, etc.	C, H_2 and O_2
3. Proteins	Lean meat, egg white, etc.	C, H_2, O_2, N, S (sometimes P)
4. Water	Water	H_2 and O_2
5. Mineral Matter	Salt, "ash" left when many different kinds of food are burned.	The following different elements have been found in ash of different foods: P, Ca, Fe, Na, Cl, S, K, Mg, I, Si, F
6. Vitamins	Abundant in milk, fresh vegetables and fruits	C, H_2, O_2

Undoubtedly, most children are familiar with the term "calorie" since American people at large have been made conscious of the word in relation to reducing diets. Yet, the chemical significance of calorie will furnish a new angle for all.

The study of diets - reducing and non-reducing - will be interesting to the students and will furnish an excellent ground for the teacher to show the chemical changes which take place in the burning up of foods and the importance which these wisely chosen diets have to individual health. The consideration of diets should give the students an understanding of the composition of foods, the computation of the amounts needed by an individual and a realization of its close connection to the health of the individual.

Composition of Some Foods
(Newell - pp. 311, 314)

	Percent					Calories/lb.
Food	Water	Carbo-hydrate	Fat	Protein	Mineral Matter	Fuel Value
Apples	84.6	14.2	0.5	0.4	0.3	290
Bacon	20.2	----	64.8	9.9	5.1	2840
Beans (dried)	12.6	59.6	1.8	22.5	3.5	1605
Beefsteak (sirloin)	61.9	----	18.5	18.6	1.0	1130
Butter	11.0	----	85.0	1.0	3.0	3491
Cheese (cream)	34.2	2.4	33.7	25.9	3.8	1950
Codfish (fresh)	82.5	----	0.3	16.3	0.9	325

(over)

Composition of Some Foods (cont'd)

	Percent					Calories/lb.
Food	Water	Carbo-hydrate	Fat	Protein	Mineral Matter	Fuel Value
Corn (green)	75.4	19.7	1.1	3.1	0.7	470
Eggs	73.7	----	10.5	14.8	1.0	720
Grapes	77.4	19.2	1.6	1.3	0.5	450
Ham (smoked)	40.3	----	38.8	16.1	4.8	1940
Mutton	52.9	----	30.9	15.3	0.9	1595
Oatmeal	7.3	67.5	7.2	16.1	1.9	1860
Peanuts	9.2	24.4	38.6	25.8	2.0	2560
Potatoes	78.3	18.4	0.1	2.2	1.0	385
Rice	12.3	79.0	0.3	8.0	0.4	1630
Tomatoes	94.3	3.9	0.4	0.9	0.5	105
Walnuts	2.5	16.1	63.4	16.6	1.4	3285

Sherman (37, p. 527) gives the following figures on the average calorie requirement per day for growing boys and girls:

Age	Calories per Day	
Years	Boys	Girls
9-10	1700-2000	1550-1850
10-11	1900-2200	1650-1950
11-12	2100-2400	1750-2050
12-13	2300-2700	1850-2150
13-14	2500-2900	1950-2250
14-15	2600-3100	2050-2350
15-16	2700-3300	2150-2450
16-17	2800-4000	2250-2600

Much time is spent in the preparation and cooking of foods. We eat celery either raw or cooked, yet we would not care to consume potatoes in the raw state. The chemical changes involved in the process of cooking and the relative digestibility of raw foods should prove to be a worthwhile topic for the subject vitally concerns the individual student.

III. Baking Powders

Why is baking powder used for pastry baking at home? Of the various brands on the market, which is the most efficient as well as most economical to use? Surely most boys will be interested in what really happens to the cake mother bakes; while many girls will wish to know what chemistry has

to do with their newly acquired art of cooking.

Although all baking powders are identical in appearance, they are actually mixtures of several different compounds.

Composition of Baking Powders

1. Sodium bicarbonate ($Na HCO_3$) - source of CO_2
2. Acidic constituent - as cream of tartar ($KHC_4H_4O_6$), calcium acid phosphate ($CaH_4(PO_4)_2$), or alum ($NaAl(SO_4)_2$), to liberate the CO_2
3. Starch or flour - a preservative for 1 and 2

The U. S. Department of Agriculture gives the following definition for Baking Powder:*

"Baking powder is the leavening agent produced by the mixing of an acid-reacting material and sodium bicarbonate, with or without starch or flour".

"It yields not less than 12 per cent of available carbon dioxide".

"The acid-reacting materials in baking powder are: (1) tartaric acid or its acid salts, (2) acid salts of phosphoric acid, (3) compounds of aluminum, or (4) any combination in substantial proportions of the foregoing".

"Other harmless substances not included in the above list may also be used in baking powders provided that their presence is mentioned on the label".

A good baking powder will contain an amount of acidic constituent sufficient to react with the full amount of bicarbonate so as to liberate the CO_2 when moistened. A powder consisting mainly of starch or flour is a poor and expensive baking powder since the chemical reaction upon which the entire process depends is relatively very small. The true value of a baking powder rests upon the maximum amount of carbon dioxide liberated. Many commercial firms stress, as part of their salesmanship, the actual

*Taken from page 517 of Sherman's "Food Products"

value and harmlessness or alum.

Greer and Bennett (23) on page 477 say: "There has been much discussion by those interested in the sale of baking powders regarding the relative harmlessness of the various brands.... Regardless of the type of baking powder, when a baking powder is moistened and heated, carbon dioxide is always formed. This, as has been explained, is the product that leavens a dough or batter. The kind of gas which is given off by all baking powders is the same. Some baking powders may produce more gas than others, and some may produce the gas more rapidly than others".

"But along with the formation of carbon dioxide, other materials which have nothing to do with the leavening of a dough or batter are formed. These substances are called the 'by-products of the use of baking powders'. They remain in the bread or cake after baking. These solid by-products determine whether or not a baking powder is harmful...."

"It is generally agreed by those disinterested in the brand that the by-products in the case of tartrate, phosphate, and alum baking powders are not harmful, provided foods leavened with baking powders are used in moderation. No food leavened with baking powder should be used in excessive quantity".

$NaHCO_3 + KHC_4H_4O_6 \rightarrow KNaC_4H_4O_6 + H_2O + CO_2$ (Tartrate Powder)

$3CaH_4(PO_4)_2 + 8NaHCO_3 \rightarrow Ca_3(PO_4)_2 + 4Na_2HPO_4 + 8CO_2 + 8H_2O$ (Phosphate) (Powder)

$2NaAl(SO_4)_2 + 6NaHCO_3 \rightarrow 4Na_2SO_4 + 2Al(OH)_3 + 6H_2O + CO_2$ (Alum Powder)

The conclusion made in a report (62) by the Referee Board of Consulting Scientific Experts (Ira Remsen-chairman) states: "In short, the board concludes that alum baking powders are no more harmful than any other baking powders but that it is wise to be moderate in the use of foods that are leavened with baking powder".

IV. Crisco

What is "Crisco" and other butter and lard substitutes? During the

World War, the spirit of patriotism plus the chemist brought to the American housewife lard and butter substitutes. The chemist found that cottonseed and other vegetable oils could be converted to solid food fats by the addition of hydrogen, in the presence of a nickel catalyst. The liquid olèin compound is thus converted to a solid stearin compound - that is, the unsaturated fatty acid radicle becomes saturated.

Considering this point, Thorp (58, p.351) states: "The unsaturated compounds of the fatty acid series unite directly with hydrogen in the presence of suitable catalysers, to form saturated bodies; thus oleic acid ($C_{18}H_{34}O_2$) is converted to form stearic acid ($C_{18}H_{36}O_2$), and olein yields stearin, which have greater commercial value, owing to their higher melting points. Platinum, palladium, copper,nickel, and other metals have been tried as catalyzers, but nickel is found most suitable, since it is highly active and of moderate cost".

Oleic acid - $C_{18}H_{34}O_2$ - unsaturated series - Melting point = 14°C
Stearic " - $C_{18}H_{34}O_2$ - saturated " - " " = 70.9°C

(Thorp page 349)

V. Sour Milk and Vinegar

Chemically, what happens to the milk when it "sours"? Why does food "spoil" or "decay"? Children in an agrarian community may be interested in the chemistry involved in fermentation of fresh foods and canned fruits and vegetables; and in the making of vinegar.

Vinegar is the result of acetic fermentation caused by a group of bacteria. It is believed that the bacteria cause the oxidation of the alcohol, probably first into aldehyde and finally into acetic acid as repressed in the following formulas:

$$2\ C_2H_5OH + O_2 \rightarrow 2\ C_2H_4O + 2\ H_2O$$
$$2\ C_2H_4O + O_2 \rightarrow 2\ C_2H_4O_2$$

(Thorp - page 463)

According to Thorp (58, p.435): "Fermentation is a general term applied to various chemical changes caused by the action of bodies called ferments. These are: (a) Unorganized chemical substances, called enzymes, secreted by living cells; and (b) certain micro-organisms".

VI. Adulteration

The work of Dr. Harvey Wiley on preservatives and the adulteration of foods ought to be brought to the attention of students in chemistry since the proposed revision of the Pure Food and Drug Act of 1906 involves chemical, economic, legal and health problems. It should bring to the student an understanding of the service of chemistry to man and to the country.

If the students desire, the teacher may outline the chemistry applied to the dietary needs of farm animals - as chickens, hogs, cows, horses, etc.

Thus, by correlation with the individual needs of the student, the topic of food and nutrition should develop an understanding of its magnitude and service to mankind.

In this unit, the following phases of chemistry could be set forth in reference to the interests and health of the individual:

1. Hydrolysis
2. Hydrogenation
3. Equations
4. Catalysis
5. Fats and oils
6. Carbohydrates
7. Vitamins
8. Enzymes
9. Chemical Computations
10. Percentage composition

Ref: Black and Conant - "Practical Chemistry"
sections - 284, 385-389

Greer and Bennett - "Chemistry"
pages - 471-481, 527-529, 553-563, 571-577, 588, 591-596, 598-599, 652-656, 661-669

Newell - "A Brief Course in Chemistry"
sections - 78, 261-262, 264, 283, 336, 399-409

Excursions

A visit to the Nutrition Laboratory of a nearby Agricultural Experiment Station (if one is available) would be very worthwhile, as the student may

there actually see the work and problems confronting the chemist and the results obtained.

Eastman Kodak Films

1. "Wisconsin Dairies"
2. "Meat Packing"
3. "New England Fisheries"
   Part 1 - Cod
   " II - Mackerel
4. "Pacific Coast Salmon"
5. "Range Sheep" (feeding)
6. "From Wheat to Bread"
7. "Body Framework" (growth)
8. "Digestion"
9. "Food and Growth"
10. "Good Foods" - (1) A drink of Water
    (2) Bread and Cereals
    (3) Fruits and Vegetables
    (4) Milk
11. "Mold and Yeast"

Supplementary Reading References:

1. Boone, Andrew R. - "How Chemistry Guards Your Health"
   Scientific American 151:296-298 (Dec. 1934)

2. Caldwell and Slosson - "Science Remaking the World"
   Chemistry and Economy of Food - H.C.Sherman p.247-264
   Our Daily Bread and Vitamins - W.H.Eddy p.265-287

3. Chamberlain, J.S. - "Chemistry in Agriculture"
   Fruits and Vegetables - E.M.Chace pp.163-185
   Fermentations on the Farm - J.J.Willaman and R.A.Gortner - pp. 186-209

   Agriculture and the Evolution of our Diet - C.F.Langworthy pp. 229-254

   Vitamins in Human and Animal Nutrition - R.A.Dutcher pp. 255-282

   Meat - its Relation to Human Nutrition and Agriculture - C.Robert Moulton - pp. 283-316

   The Chemistry of Milk and its Products - L.L.Van Slyde - pp. 335-357

4. Darrow, F.L. - "The Story of Chemistry"
   Vitamins - pp. 278-287

5. Foster, Wm. - "The Romance of Chemistry"
The Housewife's Dependence on Chemistry - Chemistry and Food and Nutrition - pp. 400-419

6. Harrow, Benj. - "The Making of Chemistry"
The Rise of Biochemistry - pp. 140-152
Chemistry in Medicine - pp. 153-163
Catalysis - pp. 196-198

7. Holmes and Mattern - "Elements of Chemistry"
Carbohydrates - pp. 315-321
Food and Nutrition - pp. 328-338

8. Howe, H. E. - "Chemistry in the World's Work"
Food and Famine - pp. 62-74
Health - pp. 153-156
Pure Food and Drugs Act - pp. 156-158

9. Howe and Turner - "Chemistry and the Home"
Chemistry in Foods and Nutrition - pp. 27-51
Food and Drug Act of 1906 - p. 262

10. Lassar-Cohn - "Chemistry in Daily Life"
Mixed Diets - pp. 63-88
Nutrative Value of Foods - pp. 89-115
Vinegar - pp. 116-123

11. Miceli, Paul - "The Relation of Chemistry to Health"
J. Chem. Ed. 5:1056-1061 (Sept. 1928)

12. Sherman, H. C. - "A Century of Progress in the Chemistry of Nutrition"
Scientific Monthly 37:442-447 (Nov. 1933)

13. Sherman, Henry C. - "Chemistry of Food and Nutrition"
(Macmillan Co. - 1927)

14. Ibid "Food Products" - (Macmillan Co. - 1930)
(For teachers use)

15. Slosson, E. E. - "Creative Chemistry"
Dietary - pp. 175-180
What Comes from Corn - pp. 181-195
Solidified Sunshine - pp. 196-217

16. Slosson, E. E. - "Keeping up with Science"
A School Child's Energy - pp. 97-99
The Chemistry of Cake - pp. 204-208
How Long Can an Animal Live Without Food? - pp. 260-261

17. Stieglitz, J. - "Chemistry in Medicine"
The Story of the Discovery of Vitamins - E.V.McCollum and N. Simmonds - pp. 112-144

The Conquest of Dietary Diseases
1. No Child Need Have Rickets - J.M.Gamble - pp.145-164
2. The Disappearance of Scurvy - A.F.Hess - pp.165-179
3. The Needless Sacrifice to Beriberi - E.B.Vedder - pp.180-190

17. Stieglitz, J. - "Chemistry in Medicine" (Cont'd)
   4. Safeguarding the foods we eat - F.O.Tonney - pp.340-357

18. Thorp - "Outlines of Industrial Chemistry"
   Solid Animal Fats - pp. 367-368
   Starch - pp. 401-411
   Fermentation - pp. 435-440
   Vinegar - pp. 463-467

19. Tower and Lunt - "The Science of Common Things"
   The Food we Eat - pp. 23-58
   The Work of Yeast Plants - pp. 335-341
   Fermentation - pp. 366-367

20. Van Buskirk and Smith - "The Science of Everyday Life"
   Food for Home and Camp - pp. 191-213
   Food - its Use and Composition - pp. 216-238
   (Good food composition charts on pp. 229-236)

   Foods and the Human Body - pp. 240-262

Optional Laboratory Work

1. Make a chart of food consumption per day or week by the individual.

2. Outline the chemical constituents and caloric intake of the individual.

3. Construction of menus - considering both, the relative nutrition value and current cost of each meal.

4. Examination of samples of baking powder brought from home.

5. Reports and comparisons of labels on commercial brands of baking powders.

6. Test samples of foods (from home) for starch, sugar, and protein content.

7. Test samples of milk.

It is expected that, from the study of Foods and Nutrition, the students shall derive an appreciation of the service chemistry renders to human health and happiness, to the home and to the country.

The topic of Acids and Bases may appear to be mainly interesting from a technical point of view. Yet acidic and basic reactions are constantly employed in a household today. Therefore, this unit should be of interest to boys and girls since it concerns their immediate surroundings.

Why, in cooking, are wooden spoons generally used for stirring? When certain fruits and vegetables such as lemons, tomatoes, etc., are cut, what causes the stain which appears on the knife. Housekeepers and manufacturers store pickles in a crock or glass container. Would not metal containers serve the purpose as well? Today, most cooking utensils are made of metal. Why then are people cautioned not to leave acid foods in tin containers?

Why are some laundry soaps harsh and injurious to the skin? What substances does a housekeeper employ to wash greasy dishes or to facilitate the spring housecleaning?

Surely, the above-mentioned questions and similar ones ought to arouse the interest of boys and girls in the chemistry of acids and bases and the role they play in their everyday life and immediate surroundings.

I. Acids

At home, the student may have had occasion to see that, in the process of laundrying, mother used bleaching water or bleaching powder to whiten and wash. The "whitening" of the clothes is dependent upon the oxidizing power of nascent oxygen which is evolved from the unstable hypochlorous acid ($HClO$).

The "bleaching water" is a solution of hypochlorous acid ($HClO$). Since the hypochlorous acid is unstable, free nascent oxygen is liberated and bleaches the clothes.

$$HClO \rightarrow HCl + [O]$$

Bleaching powder is a Calcium salt of hypochlorous and hydrochloric

acids, which on exposure to the air, absorbs moisture and carbon dioxide (CO_2) giving off hypochlorous acid (HClO). The hypochlorous acid, noted above, liberates the bleaching agent - nascent oxygen.

Black and Conant (5, p.291) write: "Since hypochlorous acid is very weak, it is easily displaced from its salts by other acids... When 'bleaching powder' is used in the household, the acid required is slowly supplied by carbon dioxide in the air. The equations are:

$$CaCl\ (OCl) + CO_2 + H_2O \rightarrow CaCO_3 + HOCl + HCl$$
$$HOCl \rightarrow HCl + [O] \text{ used up in the bleaching"}$$

Butter is said to become "rancid" on long standing or if kept in a very warm place. "It (i.e. butter fat) is very complex, containing glycerides of a number of acids of which oleic, palmetic, stearic, and butyric are the most important". (Thorp - page 367). The "rancidity" of butter is due to the formation of an excess of the volatile fatty acid - namely butyric (C_3H_7COOH).

Citric acid is another acid which will arouse the students' interest in chemistry since it is present in socalled citrus fruits, such as lemons, oranges, gooseberries, cranberries, currants, etc. The "sourness" of these fruits is due to the citric acid ($C_3H_4(OH)(COOH)_3$.

As noted in Unit V, vinegar is made by fermentation of cider to acetic acid (CH_3COOH).

$$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$$

The "sour" taste of cider vinegar is due to the acetic acid.

Thus, we find that certain acids are present in fresh foods as well as decayed foods.

Apples	- malic acid-$C_2H_3(OH)(COOH)_2$
Grapes	- tartaric acid-$C_2H_2(OH)_2(COOH)_2$
Lemons	- citric acid-$C_3H_4(OH)(COOH)_3$
Vinegar	- acetic acid-CH_3COOH)
Rancid Butter	- butyric acid-C_3H_7COOH)
Sour Milk	- lactic acid-$C_2H_4(OH)(COOH)$

(Formulas from Thorp)

The knowledge that many foodstuffs contain acids will offer the teacher the opportunity to develop the action of acids upon metals and the necessity for using the proper cooking and kitchen utensils in order to safeguard the individual's health.

Some acids (such as boric acid) play an important part in medicine and surgery, due to their antiseptic quality.

If it is desired, the topic of acids may be further developed into their importance in industry.

The problem of soil acidity and its detriment to agriculture was noted in the unit on fertilizers.

II. Bases

Lye, (NaOH) most probably, has been used in the student's home to clean out the drain pipes. The label on the can warned the user to handle the contents with care; while some brands point out the poisonous nature of the lye if taken internally.

Another alkali which is commonly used in the home is the socalled "household ammonia". Ammonia (NH_4OH) is important for certain cleaning processes such as the removal of dirt and grease from kitchen walls, dirty dishes, etc.

The following are alkalies commonly used in cleaning processes in the home:

Name	Formula
1. Household ammonia	NH_4OH
2. Soda lye (or caustic soda)	$NaOH$
3. Washing soda (or sal soda)	$NaCO_3 \cdot 10H_2O$
4. Borax	$Na_2B_4O_7 \cdot 10H_2O$ or ($Na_2B_4O_7 \cdot 5H_2O$)
5. Laundry soap	$C_{17}H_{35}COONa$

All of these substances are good cleaners in that they possess OH ions in solution.

Greer and Bennett (23, p.461) write that: "In the days of the colonists, washing soda was unknown as a household substance. Housekeepers prepared a substance from wood ashes which was effective in cleaning. They called it lye. It was not, however, the compound sodium hydroxide - which we now call lye. It was mostly potassium carbonate. Potassium carbonate is no longer prepared in the home nor is it generally used for cleaning purposes".

The chemist now prepares many household needs which formerly were made as part of the routine household work.

What, chemically, is the difference between washing soda, soda lye, and baking soda? A student may ask this question since all three substances are fairly commonly used in the home. The teacher may, thereby, introduce formation of different salts as exemplified by soda lye ($NaOH$), washing soda (Na_2CO_3), and baking soda ($NaHCO_3$).

III. Soap

Soap, found in every home, school, etc., is a product of the chemist. Surely, boys and girls will ask how soap is made and how it cleans.

The entire industry of soap making is dependent upon the chemical reaction of a fat (usually stearin) and a base as NaOH. The resultant soap is a sodium ester of a complex acid.

$$(C_{17}H_{35}COO)_3C_3H_5 + 3NaOH \rightarrow 3\overbrace{C_{17}H_{35}COONa}^{\text{soap}} + C_3H_5(OH)_3$$

The chemist by selection of raw materials, has been able to make many kinds of soap - all the way from a harsh yellow laundry soap to a mild, scented toilet soap. The difference is due to the quality and type of fat used. For example, in making toilet soaps the best grades of tallow, tallow oil, etc., are mixed with lye free from impurities, while poorer grades of tallow, bone grease, etc., plus rosin are used for laundry soaps. In the making of toilet soaps, care is taken to remove any excess of alkali, and various perfumes are added.

Soap Production in U. S.
(page 732 - Statistical Abstracts 1933)

Product	Quantity (thousands of lbs.)			Value (thousands of dollars)		
	1927	1929	1931	1927	1929	1931
Hard Soaps (total)	2,435,148	2,587,955	2,572,895	212,475	235,581	197,185
toilet soaps	287,696	324,383	305,638	53,573	59,983	53,064
soap chips	373,216	387,925	351,077	39,422	41,764	30,353
Laundry and foot soap	1,502,183	1,487,012	1,451,119	93,092	93,866	69,598
All other hard soaps	56,133	51,343	43,257	5,371	4,243	3,193
Soap Powders	484,464	505,529	426,779	24,024	23,387	18,442
Soft Soaps	79,773	66,141	42,285	4,231	3,951	2,247

In days gone by, soap making was another "home industry". The housekeeper had to make many home necessities which today have been perfected and improved by the chemist.

Considering this point, Foster (17, p.133) relates: "Soap-making is ... a chemical reaction carried out on a large scale. It was learned by certain of the ancients that grease could be removed from the hands by washing them with wood-ashes. The Gauls prepared a sort of crude soap by mixing wood-ashes, water, and goat's tallow; and with this they washed their hair and beards in order to give them a fiery-red color which they regarded as becoming. The Romans no doubt learned something from the Gauls, and they were perhaps the first civilized people to prepare real soap".

"Years ago, in our own country, soap-making, like weaving and spinning, was one of the household arts or industries. Soap was made by dissolving the potash out of wood-ashes by means of water or lime-water, the solution being known as lye. The fat, or soap-grease, saved by the housewife was heated in iron kettles with potash lye, soft soap being obtained".

"In case sodium hydroxide, or caustic soda, was purchased at the grocery and substituted for potash, hard soap was obtained".

While Greer and Bennett (23, p.604) say: "In colonial days when soap was made in the home, only soft soap was produced. This was due to the fact that the so-called lye used in domestic soap making was obtained from wood ashes and was a potassium (not sodium) compound".

If desired, the class may consider in detail the making of different brands of soap - such as hard soaps, soft soaps, transparent soaps, "floating" soaps, colored soaps, scented soaps, borax soap, laundry (yellow) soaps, etc. - soap powders, scouring powders, and shampoos.

(See Thorp - 58, pp.373-379 - for references)

Considering the cleansing action of soap, Newell (34, p.305) states: "This is ascribed to two causes: (1) Soap hydrolyses, i.e. interacts with water - especially hot water - and the liberated alkali (NaOH) acts upon the grease and oil that is usually mixed with the dirt; (2) soap causes fat and grease to form colloidal suspension - the minute globules remain suspended in water and absorb the dirt, and the whole can be readily washed off. The second cause is the more efficient".

The study of the unit on acids and bases should bring to the students an understanding of the close connection of chemistry with daily life.

Considering points of vital interest to the student, the following phases of chemistry may be developed under Acids and Bases as related to his daily life:

1. Saponification
2. Deliquescence and efflorescence
3. Nascent state
4. Water of crystallization
5. Ionization
6. Hydrolysis
7. Neutralization
8. Formation of salts
9. Displacement reactions
10. Dehydration

Ref: Black and Conant - "Practical Chemistry"

sections - 150-152, 155, 231, 233-234, 283, 285-286, 301-302, 337, 372, 382-384

Greer and Bennett - "Chemistry"

pages - 220-238, 243-255, 460-469, 471-473, 478, 526-529, 534-535, 566-567, 592-594, 602-607

Newell - "A Brief Course in Chemistry"

sections - 58, 125-126, 185, 195-196, 264, 278, 280-282, 286, 289, 393-395

Eastman Kodak Film

1. "Soap"

Supplementary Reading References:

1. Darrow, F. L. - "The Story of Chemistry"
   Chemistry in the Day's Work - pp. 451-460

2. Foster, Wm. - "The Romance of Chemistry"
   Acids and Alkalies - pp. 129-132
   Soap Making - pp. 132-136
   Salts and Their Names - pp. 136-144

3. Holmes and Mattern - "Elements of Chemistry"

   Soaps - pp. 309-311
   Sal Soda - p. 383
   Caustic soda - p. 381
   Baking soda - p. 388

4. Lassar-Cohn - "Chemistry in Daily Life"
   Soap Making - pp. 191-198

5. Thorp, F. H. - "Outlines of Industrial Chemistry"
   Soap - pp. 372-379
   Butter Fat - p. 367
   Bleaching - p. 501
   Bleaching Water - p. 131
   Bleaching Powder - p. 132
   Soda Crystals - p. 100
   Borax - pp. 261-263

Optional Laboratory Work

1. Test common foods with litmus paper and note acid foods
2. Preparation of HCl from salt and H_2SO_4
3. Observe acidic and basic affects on samples of cotton, wool, silk, and skin (with caution)
4. Make some soap
5. Make limewater

6. Bleach a sample of cotton cloth
7. Engrave a knife blade with an acid

It is hoped that the consideration of some acids and bases shall give to the students an understanding and appreciation of the service of chemistry to the home.

Iron, with its various alloys and compounds, should be of immediate interest to students in an agrarian community in that it greatly concerns their environment. Plants and animals need in their dietary minute amounts of iron; yet iron is used in the construction of buildings, household utensils and furnishings, agricultural apparatus, trains, automobiles, fences, tools, etc.

One may only surmise what might have been the status of agriculture today if modern farming apparatus had not been developed. Farm equipment has been made possible by the research chemist who has worked upon iron and its compounds.

Darrow (13, p. 333) points out that:..."in a multitude of ways, steel is indispensable to agriculture. A steel plow, drawn by a steel tractor, turns under the sod in the spring. Steel harrows and disks fit the ground. A steel drill sows the seed. Tractor-drawn reapers of steel cut the ripened grain. Threshing-machines of steel separate the wheat, barley, rye and oats. Elevators of steel hold the grain in storage. Steel trains and ships carry it to distant markets. The gasoline motor and a score of machines of high-grade steel have become the willing burden bearers of the farm".

On page 738, of the Statistical Abstracts of the United States (1933) appears the following data on the production of farm equipment:

Production of Farm Equipment

Class	1928	1929	1930
1. Plows and listers	$524,255,000	$606,622,000	$507,002,000
2. Harrows, rollers, pulverizers and stalk cutters	14,687,000	16,813,000	13,815,000
3. Planting and fertilizing machinery	26,505,000	31,145,000	26,087,000
4. Cultivators and weeders	15,864,000	22,857,000	21,892,000
5. Harvesting machinery	67,291,000	87,713,000	62,145,000
6. Haying machinery	16,058,000	18,711,000	17,186,000

(cont'd over)

Production of Farm Equipment (cont'd)

Class	1928	1929	1930
7. Machines for preparing crops for market or use	$ 33,466,000	30,103,000	20,760,000
8. Tractors	191,978,000	227,633,000	205,657,000
9. Horse drawn vehicles	9,974,000	8,813,000	4,948,000
10. Miscellaneous equipment	116,273,000	120,469,000	96,682,000

Number of Farm Machinery and Facilities - 1930
(Statistical Abstracts of the U. S. - 1933)
page 556

	Number in use	Number of farms reporting	Percent of total farms
Telephones	--,-------	2,139,194	34.0
Automobiles	4,134,675	3,650,003	58.0
Motor trucks	900,385	845,335	13.4
Tractors	920,021	851,457	13.5
Electric motors for farm work	386,191	256,663	4.1
Stationary gas engine	1,131,108	945,000	15.0

The above data shows that many forms of farm equipment are being used in agricultural regions of the United States. Therefore, it is plausible to assume that children will be interested in the chemical elements and the factors which have made possible the manufacture of the facilities that father uses in his daily work.

What is the difference between stainless and ordinary knives? What factor has made the apparent difference in the iron kitchen stove and the steel body of the automobile? What causes an iron fence to rust and how can rusting be prevented?

Referring to known objects, the teacher may create an interest in the importance and manufacture of iron products.

"Iron", state Black and Conant (5, p. 408) "is doubtless the most valuable metal in the world. Not that it is so costly; indeed its value rests upon its cheapness and its adaptability to an enormous number of uses. It

has in fact become a necessity in our modern life.... Particularly in our country has the industry of iron and steel production reached such high proportions that the yearly output approximates thirty million tons".

Output of Pig Iron (tons)
(Encyclopaedia Britannica - p.673)

Year	World	United States
1820	1,000,000	-------
1830	1,800,000	-------
1840	2,700,000	-------
1850	4,700,000	630,000
1860	7,220,000	820,000
1870	11,840,000	1,670,000
1880	18,160,000	3,840,000
1890	26,750,000	9,200,000
1900	39,810,000	13,790,000
1910	64,760,000	27,300,000
1913	77,900,000	30,970,000
1920	62,850,000	36,930,000
1921	37,680,000	16,690,000
1922	54,780,000	27,220,000
1923	68,910,000	40,360,000
1924	67,200,000	31,410,000
1925	75,920,000	36,700,000
1926	77,700,000	39,370,000
1927	85,270,000	36,570,000

I. Metallic Iron

Free iron does not occur in nature, but it is obtained by smelting the ores - namely oxides.

Newell (34, p.232) says: "Combined iron is found in most rocks, soils and natural waters. It is assimilated by plants and animals and is essential to their life processes, being a constituent of chlorophyll (the green coloring matter of plants) and of haemoglobin (the red coloring matter of blood)".

Iron Ores

Common Name	Chemical Name	Formula
haematite	ferric oxide	Fe_2O_3
magnetite	magnetic oxide	Fe_3O_4
limonite	hydrated ferric oxide	$2Fe_2O_3 \cdot 3H_2O$
siderite	ferrous carbonate	$FeCO_3$

The student may ask: "why is it necessary to name and specify iron as wrought, cast, or steel?" "Wherein lies the difference?"

The three main varieties of commercial iron should be considered since the uses of the products are dependent upon the characteristics of the specific type.

Th

Type	Iron Content	Impurities (Percent)				
		C	Si	Mn	P	
1.Cast Iron	94%	3-4	1-3	0.7	0.7	. .
2.Wrought Iron	99%	0.5	---	---	---	-
3.Steel	98%	.05-1.6	trace	trace	trace	tr

II. Special Steels and Iron Alloys

What are special steels and why should they be considered in an elementary course of study? When iron is melted with definite proportions of certain metals, the so-called special steels result which, due to their specific qualities, have found distinct purposes.

Writing in 1927, Howe and Turner (27, p.59) state: "Within the last twenty years chemists have been working diligently on a study of effects produced when various of the rare elements are added in small quantities to ordinary steel. And some very surprising results have been achieved. Practically all of these rare elements confer peculiar and valuable properties on the steel if added in just exactly the right amount. Nickel confers certain properties of toughness and ductility; tungsten enables tool-steel to retain its cutting edge at a temperature far above that at which ordinary steel

Three Types of Iron

Type	Iron Content	Impurities (Percent)					Method of Smelting	Method of Production	Melting Point	Use
		C	Si	Mn	P	S				
1. Cast Iron	94%	3-4	1-3	0.7	0.7	.02-.05	Blast Furnace	Molded in Casts	1200°C	stoves, pipes, railing radiators, etc.
2. Wrought Iron	99%	0.5	---	---	---	---	Reverberatory	Forged and Welded	1500°C	wire, rods, rivets, nails, spikes
3. Steel	98%	.05-1.6	trace	trace	trace	trace	(a) Bessemer (b) Open-hearth (c) Cementation (d) Crucible (e) Electric Furnace	Forged, Welded or Cast	1400-1500°C	shafts, axles, tools, springs

would lose its temper; vanadium gives valuable properties of resistance to fatigue and enables steel successfully to resist constantly repeated strains, as in the case of railway springs; manganese makes steel exceedingly hard, a and is used for rails, burglar-proof safes, jaws, or rock-crushers, and other such equipment".

The following are some of the special steels and iron alloys finding vast usage:

1. Invar
2. Platinite
3. Stainless steel
4. Chromium steel
5. Manganese steel
6. Tungsten steel
7. Molybdenum steel
8. Duriron

Darrow (13, p.339) writes: "Stainless steels and rustless iron are meeting a host of needs in our homes, farms and workshops. The element which confers this property is chromium. When present in percentages between twelve and fourteen, together with from a quarter to four-tenths per cent of carbon, the product is stainless steel, so widely used in cutlery. But to obtain this property of stainlessness special heat-treatment is essential. Heating to a bright red followed by rapid quenching produces an alloy of iron and chromium which retains in solution carbides of these two metals, thereby preventing an otherwise corrosive action. Chromium also imparts great strength and resistance to abrasion. Rustless iron differs from stainless steel in having much less carbon, usually less than a tenth per cent. It requires no heat-treatment, for few carbides are present, and it is softer than stainless steel, being easily rolled, forged and cold-worked. The softness of rustless iron limits the field of usefulness. For instance, it can not be employed in the making of tools and cutlery. Still its applications are numerous, and rustless iron is a decided chemical triumph. Used in proportions of twenty per cent and more, chromium increases, to a much higher degree, the resistance to the action of corroding substances. Such iron-chromium alloys will resist oxidation up to temperatures of 1100 degrees

Centigrade".

III. Rusting

Iron is attacked by the atmosphere producing a reddish brown powder, which adheres only loosely to the metal. Thus the iron is again exposed resulting in more rust formation.

The chemist has found that rusting may be prevented by: (1) painting the iron surface; (2) coating the surface of a kitchen utensil with enamel (such as the enamel pan); (3) covering the surface with a thin layer of zinc or tin - (as in the so-called "galvanized iron" and "tin utensils").

The teacher may also develop the chemical changes involved in the making and use of blue-black inks as contrasted with India inks; ink stains and their removal; and the importance of iron compounds in the making of blue prints.

The topic of Iron and Steel has been treated in such a manner as to relate the chemistry involved to the student's daily life.

In this unit, the following chemical points may be discussed in the light that they relate to the student's environment:

1. Oxidation - reduction
2. Alloys
3. Nickel, zinc, enamel plating
4. Neutralization

Ref: Black and Conant - "Practical Chemistry"
sections - 426-438, 439-448

Greer and Bennett - "Chemistry"
pages 100-102, 174-179, 277-278, 348, 743-766

Newell - "A Brief Course in Chemistry"
sections - 304-322, 407

Eastman Kodak Films

1. "Iron Ore to Pig Iron"
2. "Pig Iron to Steel"

B. U. School of Education - Film Service

1. "Making an all Steel Automobile Body"
2. "Metals of a Motor Car"
3. "The Story of Steel" - 1 and 2. Basic Processes of making Steel
   3. Manufacture of Rails, Plate and other hot rolled products
   4. Manufacture of Wire Products
   5. " " Pipe "
   6. " " Sheet Steel

Supplementary Reading References:

1. Darrow, F. L. - "The Story of Chemistry"
   The Age of Metals - pp. 329-344

2. Foster, Wm. - "The Romance of Chemistry"
   The Marvelous Story of Iron and Steel - pp. 287-307

3. Harrow, Benj. - "The Making of Chemistry"
   Iron and Steel - pp. 173-178

4. Holmes and Mattern - "Elements of Chemistry"
   Iron and Steel - pp. 438-459

5. Howe, H. E. - "Chemistry in the World's Work"
   Metals, the Master - pp. 105-116
   Permanency of Possessions (rusting of metals) pp. 131-137

6. Howe and Turner - "Chemistry and the Home"
   Metals in the Kitchen - pp. 57-66

7. Lassar-Cohn - "Chemistry in Daily Life"
   Iron and Steel - pp. 253-281

8. Slosson, E. E. - "Creative Chemistry"
   Metals, Old and New - pp. 263-285

9. Ibid - "Keeping up with Science"
   The Composition of the Earth - pp. 167-170.
   Why Metals get Tired - (Iron and Steel) pp. 321-325

10. Thorp, F. H. - "Outlines of Industrial Chemistry"
    Iron and Steel - pp. 601-610

Optional Laboratory Work

1. Classify the iron and steel articles found in the student's home.

The study of this unit should present to the students an appreciation of the importance of iron and steel in the world today and its relation to an agricultural community.

Dyes and paints do not seem to be very essential to life, yet life has been made more enjoyable through these substances since they furnish the colors which scatter brightness and happiness.

Children should be interested in dyes and paints for they predominate throughout their daily lives.

There are many colors and shades. How are they produced? How are the clothes they wear colored? In painting a house, what type of paint is most economical from the point of view of long wear as well as material cost? Should the same paint be used on indoor surfaces as well as outdoor surfaces? We say that paints dry - chemically, what actually happens in the processes? In laundering, some colors "run" while others are "fast". What is the difference? How is father's automobile painted?

Thus, a teacher may arouse an interest on the topic of dyes and paints, since the students see that they concern their clothes and their surroundings.

I. Dyes

"Dyes" say Black and Conant (5, p.464): "are colored substances which can be firmly attached to textiles either directly or with the help of a colorless compound called a mordant".

The manufacture of dyes in the United States is comparatively a modern industry. In fact, very little was produced in this country before the World War.

Foster (17, p.437) relates: "German chemists, engineers, and manufacturers spent half a century in building up a great dye industry. When the war broke out in 1914, other nations were largely dependent on Germany for an adequate supply of fast dyes. In 1915 a single keg of dye sold for

$1500, while the normal price had been about $15. The story of the trips of the submarine 'Deutschland' with its cargoes of aniline dyes, valued at millions of dollars, reads like a romance, so full is it of adventure. Dyes were so scarce in the United States that hundreds of chemists were put to work to solve the problem of producing them on an industrial scale; and it will always be a bright page in the history of American chemistry that before the war ended we had an independent dye industry destined to rival that of Germany".

Considering the shortage of dyes in the United States during the early part of the World War, Darrow (13, p.415) writes: "At that time, the United States produced less than three per cent of the world's output of synthetic dyes, and yet we consumed a larger proportion than any other nation".

On page 416, he goes on to say: "For two years we managed to get along with existing stocks or went without. In 1916, there were only seven dye factories in the country. By the end of 1917, they had increased to eighty-one, and the output of dyes was about forty-six million pounds, - equal to the pre-war importation.... We are today (i.e.1927) meeting about ninety-five per cent of domestic consumption and our exports exceed imports. In 1926 88,000,000 pounds of coal-tar dyes were produced here".

Unfortunately, previous to 1917, the production of coal-tar dyes was considered as part of the chemical industry, and therefore no figures are available to show the immense increase in our domestic production of coal-tar dyes.

The Fourteenth Census (66, p.651) of the U. S. taken in the year 1920 states: "At prior censuses the coal-tar industry has been carried as a group of the general chemical industry. Comparative figures, therefore, with respect to the general statistics are not available, as the establishments of the census of 1914 and prior censuses were included with other chemical es-

tablishments".

In 1914, the United States produced however 12,169,635 lbs. of coal-tar dyes, but these dyes were made from stock imported from foreign countries (66, p.630).

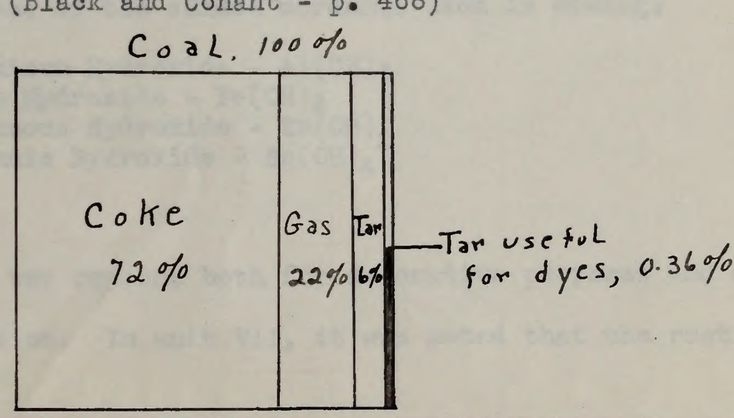
While the United States Tariff Commission (67, p. 13) reports that in 1917, the United States produced 45,977,246 lbs. of dyes, but of this total only 290,100 lbs. (less than 3% of pre-war imports) were made from domestic stock.

On page 423 of the 1935 World Almanac appear the following figures on the production of coal-tar dyes in the United States since 1918:

Year	Dyes pounds	Year	Dyes pounds
1918	58,464,446	1926	87,978,624
1919	63,402,194	1927	95,167,905
1920	88,263,776	1928	96,625,451
1921	39,008,690	1929	111,421,505
1922	64,632,187	1930	86,480,000
1923	93,667,524	1931	83,526,000
1924	68,879,000	1932	71,269,000
1925	86,345,438	1933	100,952,778

A teacher should not fail to point out that although dyes are commonly called coal-tar products, they are not present in coal-tar but are prepared synthetically by the chemists from the aromatic hydrocarbons present in coal-tar - obtained by distillation of coal.

By-products Obtained in the Distillation of Coal
(Black and Conant - p. 468)



The students may ask what dyes are used for woolens. Can the same type be used for all materials - such as wool, silk, cotton or rayon? How are colors made "fast"?

Thorp (58, p.531) states: "The commercial dyes may be grouped, according to the method of their application to the fibre, into eight classes:

1. Direct dyes, yielding full colors on all fibres without mordants

II. Basic dyes, which form insoluble tannates and require mordants on vegetable fibres, but color animal fibres without mordants.

III. Acid dyes, which require no mordant on animal fibres, but are only of limited use with vegetable fibres, mordanted or not.

IV. Mordant dyes, which require metallic mordants on both animal and vegetable fibres.

V. Acid-mordant dyes, which will dye animal fibres directly, but require mordants for the development of full and fast colors.

VI. Sulphide colors which dye vegetable fibres from alkaline baths containing sodium sulphide (Na_2S) in solution.

VII. Vat dyes, which require reduction to a soluble form in dilute alkaline solution, followed by reoxidation of the dyestuff on the fibre, to develop the color.

VIII. Ingrain colors, which are produced directly from their constituents upon the fibre".

The following are some of the common mordants used in dyeing:

Aluminum Hydroxide - $Al(OH)_3$
Iron Hydroxide - $Fe(OH)_3$
Stannous Hydroxide - $Sn(OH)_2$
Stannic Hydroxide - $Sn(OH)_4$

II. Paints

Paints are used for two reasons both for decorative purposes and as a protection against corrosion. In unit VII, it was noted that the rusting

of iron is prevented or stopped by a film of paint or by other means. The iron surface is thus protected from oxidation due to atmospheric conditions.

In housepainting, is it necessary to apply different types of paints for the walls and for the floors? What imparts colors to paints? One often hears of the "little old red schoolhouse". Why were most school buildings, in former years, usually painted red? Why is paint sealed in airtight cans?

Paints are chemical mixtures of (1) a vehicle - a liquid which on drying changes to a flexible, transparent material; and (2) a pigment which imparts color to a surface.

The student may have heard or has used a quick drying paint. What caused the "drying"? Why should some paints dry more quickly than others?

The "drying" process is the result of oxidation or evaporation of one of the constituents of paints.

Chemically, paints are divided into the following classes:

Type	Vehicle	Method of Drying	Component(s)
Water color	Water and glue	evaporation of water	a pigment
Oil Paints	Drying oil (as - linseed oil)	oxidation of oil of unsaturated organic acid	a pigment
Varnishes:			
(a) Spirit Varnish	Alcohol, acetone, petroleum spirit	evaporation of the solvent. Oxidation	a resin
(b) Turpentine Varnish	Oil of turpentine	evaporation	a resin
(c) Linseed Oil Varnish	Linseed Oil	oxidation and evaporation	a resin and turpentine
Shellac	Alcohol	evaporation	natural gum
Lacquers (quick drying - used in Duco paints)	Solution of pyroxylin and a plasticizer	evaporation	a pigment

Thorp (55, p.222) writes: "The durability of a paint depends on the chemical stability of the mixture of pigments and vehicle composing the film, and on its mechanical strength, resistance, and impermeability. These properties are best secured by using a mixture of relatively coarse and fine pigments; the first form a skeleton of large particles, giving strength and rigidity, and the latter render the mass impermeable by filling the voids between the coarse particles".

Usually, to the oil paints are added first, the so-called "dryers", like lead, manganese, and cobalt soaps which accelerate the oxidation of the oil; and second, a thinner, turpentine, which hastens the drying of the paint by its catalytic action and by evaporation.

The multitude of colors, which go to satisfy our sense of beauty, are obtained by addition of specific pigments. Most pigments are complex compounds, whose formulas are still questioned by chemists. A few are natural minerals, but most all are synthesized now and thus are less expensive.

Thorp notes the following pigments; formulas, and common and chemical names:

Shade	Common and Chemical Name	Formula
White	White lead - basic lead carbonate	$2PbCO_3,Pb(OH)_2$ *
	White zinc (or chinese white) - zinc oxide	ZnO
	Zinc white - zinc sulphide	ZnS
	Lithopone - barium sulphate and zinc sulphide	$BaSO_4+ZnS$
	Barytes - barium sulphate	$BaSO_4$
	Whiting (or Paris white) - calcium carbonate	$CaCO_3$
Blue	Ultramarine - probably a double silicate of sodium (lapis lazuli as a mineral) and aluminum with a sulphide of sodium	
	Prussian blue (or Berlin blue) - ferric ferrocyanide	$Fe4(FeCN_6)3$

*Formulas starred are questioned as to their accuracy

-cont'd-

Shade	Common and Chemical Name	Formula
	Turnbull's blue - ferrous ferricyanide	$Fe_3(FeCN_6)_2$
	Mountain blue - hydrated copper carbonate (azurite mineral)	$2CuCO_3,Cu(OH)_2$
Green	Malachite - basic copper carbonate	$CuCO_3,Cu(OH)_2$
	Verdigris - basic copper acetate	$2Cu(C_2H_3O_2)_2 + CuO$*
	Paris (or emerald) green - Aceto - arsenite of copper	$Cu(C_2H_3O_2)_2 \cdot Cu_3As_2O_6$
Yellow	Chrome yellows - lead chromate	$PbCrO_4$
	zinc "	$ZnCrO_4$
	barium "	$BaCrO_4$
	Orpiment (royal yellow) - arsenic trisulphide	As_2S_3
	Litharge - lead monoxide	PbO
Orange	Orange mineral - lead tetroxide	Pb_3O_4
	Antimony orange - antimony trisulphide	Sb_2S_3
Red	Red lead - lead tetroxide	Pb_3O_4
	Chrome red - basic lead chromate (called Chinese red, American vermillion and Victoria red)	$PbCrO_4 \cdot PbO \cdot H_2O$
	Venitian red - ferric oxide	Fe_2O_3
	Vermillion (Cinnabar)-mercuric sulphide	HgS
	Realgar - arsenic disulphide	As_2O_3
Brown	Umbers - complex mixtures of silica, alumina, iron, manganese, lime and others	
	Sepia - organic pigment secreted by the cattle-fish	
Black	Lampblack - incomplete combustion of organic substances	) used for) drawing and) printer's ink
	Carbon black - burning of natural gas	
	Bone black - charring of bones	
	Charcoal	
	Graphite - used mainly in stove polish	

Paints and varnishes are important chemicals and are used extensively - as exemplified by the following chart:

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*Formulas starred are questioned as to their accuracy.

Production of Paints and Varnishes
(Statistical Abstracts of U.S. - p.732)

Product	Unit	Quantity (thousands of units specified) 1927	1929	1931	Value (thousands of dollars) 1927	1929	1931
Pigments	lb.	1,773,889	1,918,459	1,296,006	105,756	116,753	69,428
Paints in paste form	"	408,722	401,546	242,528	49,554	46,666	26,191
Ready mixed paints	gal.	94,071	106,165	78,249	165,664	178,242	121,156
Water paints	lb.	122,456	155,811	122,823	6,321	7,093	5,265
Plastic "	"	-------*	-------*	14,561	-------*	-------*	1,393
Varnishes Japans Lacquers Enamels	gal.	106,452	126,874	88,209	178,231	204,881	125,370
Fillers liquid	"	566	495	204	722	683	236
dry	lb.	41,486	30,613	19,486	2,109	1,954	975

*Data not reported separately

The presentation of the topic of dyes and paints should bring to the student an understanding of the close relation of the service of chemistry to his home, to himself and to his everyday life.

The following chemical theories may be developed by correlation with things familiar to the everyday environment of the students:

1. Synthesis
2. Adsorption
3. Organic solutions
4. Slow and rapid oxidation
5. Reduction
6. Evaporation
7. Fractional distillation
8. Fixing color by mordants

Ref: Black and Conant - "Practical Chemistry"
sections - 490-504

Greer and Bennett - "Chemistry"
pages - 103,143,387,399,443-444,450,458

Newell - "A Brief Course in Chemistry"
sections - 266, 397, 473, 509-510, 517-522

Thorp - "Outlines of Industrial Chemistry"
pages - 222-248, 396-398, 528-544

Eastman Kodak Film

1. "Lead"

Supplementary Reading References

1. Caldwell and Slosson - "Science Remaking the World"
   The Influence of Coal-Tar on Civilization - E.E.Slosson - pp. 48-76

2. Darrow, F. L. - "The Story of Chemistry"
   Synthetic Dyes - pp. 366-367
   Lacquers - pp. 404-405
   Dyestuffs in America - pp. 415-422
   Rise of the Lacquer Industry - pp. 445-448

3. Foster, Wm. - "The Romance of Chemistry"
   Coal-tar and Dyes - pp. 378-381

4. Harrow, Benj. - "The Making of Chemistry"
   Perkin and Coal-tar Dyes - pp.92-99

5. Holmes and Mattern - "Elements of Chemistry"
   Lampblack - p. 253
   Coal-tar Dyes - pp. 312-313
   Lead Pigments - pp. 475-477

6. Howe, H. E. - "Chemistry in the World's Work"
   Dyes - pp. 76-79
   Paints - pp. 95-99

7. Howe and Turner - "Chemistry and the Home"
   Protective and Decorative Coatings - pp. 210-222

8. Lassar-Cohn - "Chemistry in Daily Life"
   Oil Painting - pp. 159-162

9. Slosson, E. E. - "Creative Chemistry"
   Coal-tar Colors - pp. 60-93

10. Ibid - "Keeping up with Science"
    A Magic Bath - pp. 193-196
    Varnishes - p. 128

11. Thorp, F. H. - "Outlines of Industrial Chemistry"
    Pigments - pp. 222-248
    Vegetable Drying Oils - pp. 357-359
    Shellac - pp. 396-397
    Varnishes - pp. 397-398
    Dyeing - pp. 528-546
    Textile Printing - pp. 546-551
    (for advanced pupil)

12. U. S. Tariff Commission - "Census of Dyes and Coal Tar Chemicals-1917"
History of the Dye Industry in the U.S. since the beginning of the European War - pp.41-52

Optional Laboratory Work

1. Dye samples of cotton, wool, and silk with and without mordants, repeating with the different types of dyes

Excursion

If at all feasible, a visit to a dyeing plant would be most worthwhile, as there a child may see and marvel at the vast processes involved in the dyeing of the textiles - from which our clothes are made.

The study of this unit on Dyes and Paints is expected to create for the students an understanding and appreciation of the service of chemistry to art, to home, to industry and to the happiness of the individual.

This paper has attempted to set up specimen units for a course in chemistry which will give the students an understanding and appreciation of the true role that chemistry plays in everyday life in an agrarian community. Throughout, the students' vital interest have governed the selection of material.

Twiss (59, p.359) well sums up my views with these words: "It follows, therefore, that facts that are most closely related to the pupils previous and concurrent experiences, facts about the behavior of those substances when reacting on one another, - especially facts that pupils are most likely to meet with and need to use in their daily lives, now or after they have finished with school, are the ones that should receive first consideration when choice of content for the course is made. Such facts should have preference over those that have value only as illustrating the theoretical side of chemistry".

On page 360 he goes on to say: "Give them (i.e. pupils) only so much of theory as will help them better to interpret and organize the facts that they have become acquainted with in the laboratory, at the demonstration table, and in the world outside, in the home, on the streets, in the factories, or on the farm".

Twiss (59, p.361) cites the following words of Professor Louis Kahlenburg: "A High School course in chemistry should endear the study of natural phenomena to the student, and lead him to see the important relationships between the chemical changes that are going on about us all the time, and the other phenomena of our everyday existence".

In conclusion Twiss states: "It is to be feared that the latter end, though universally regarded as a prime desideratum, is not reached by overmuch attention to the theoretical side of chemistry".

Thus, the teaching of chemistry <u>can</u> be placed on a functional basis, so that students may become acquainted with the true place chemistry holds in our daily life.

Many educators state that facts learned in school are retained in future life only in so far as they lie within the actual experiences of the students.

It has been my experience, many, many times to hear high school graduates and college students say: "Oh, yes, I studied that 'awful' chemistry. I spent hours memorizing page after page!" Upon further questioning they have added: "Why, I don't remember much about it - but I know that the formula for water is H_2O."

This paper, I hope, has shown that the teaching of chemistry should and can be presented so as to create an appreciation and true understanding of its full import to life situations and still be placed within the students' present or immediate future experiences.

I feel that the units developed in this paper will accomplish this, and leave with the students something more worthwhile and valuable than the point of view that chemistry is a complex subject wherein one is expected to memorize a number of laws and definitions which are soon forgotten, and wherein one learns that water equals H_2O.

1. Barber, Frederick D. - "The Reorganization of High School Science"
Sch.Sci.Math. - 18:247-62 (March 1918)

2. Barber, Frederick D. - "Fundamental Consideration in the Reorganization of High School Science"
Sch. Rev. - 24:724-34 (Nov. 1916)

3. Barber, Frederick D. - "Inadequacy of Scientific Teaching in our Schools"
Lit. Digest - 48:199 (Jan. 31, 1914)

4. Bateman, G. M. - - - - "Trends in Science Teaching"
J. Chem. Ed. - 11:540-42 (Oct. 1934)

5. Black and Conant - - - "Practical Chemistry"
(revised - Macmillan Co. - 1927)

6. Board of Public Ed. - Pittsburgh, Pa. - "High School Course of Study in Chemistry"
Bulletin No. 22

7. Bray, W. J. - - - - - "The Function of Chemistry in the Modern High School"
Sch. Sci. Math. - 12:572-77 (Oct. 1912)

8. Bruce, G. V. - - - - - "An Attempt to Vitalize Chemistry Teaching in the High School Through a Modified Form of the Unit Assignment Technic"
Sci. Ed. - 16:392-403 (Oct. 1932)

9. Caldwell, Otis W. - - "Preliminary Report of the 'Committee of a Unified High School Science Course' (appointed by the Central Association of Science and Mathematic Teachers)"
Sch. Sci. Math. - 14:166-68 (Feb. 1914)

10. Chamberlain, J. S. - - "Chemistry in Agriculture"
(The Chemical Foundation - 1927)

11. Coulson, Francis O. - "Educational Aims in Teaching Elementary Chemistry"
J. Chem. Ed. - 6:1120-25 (June 1929)

12. Curtis, Harry A. - - - See Chamberlain (10)

13. Darrow, Floyd L. - - - "The Story of Chemistry"
(Bobbs Merrill Co. - 1930)

14. Encyclopaedia Americana (Americana Corporation 1932)

15. Encyclopaedia Britannica (1932)

16. Foster, L. F. - - - - - "What are our Objectives in Teaching Chemistry"?
J. Chem. Ed. - 2:971-99 (Nov. 1925)

17. Foster, Wm. - - - - - - "Romance of Chemistry"
(Century Co. - 1927)

18. Frank, J. O. - - - - - "The Teaching of High School Chemistry"
J. O. Frank and Sons - Oakkosh,Wis. (1932)

19. Galloway, T. W. - - - - "Report of the 'Committee on Fundamentals' of the Central Association of Science and Mathematic Teachers"
Sch. Sci. Math. - 10:801-13 (Dec. 1910)

20. Gattis, W.E. & S.M.Marrs - "The Teaching of Science"
Bulletin of State Dept.(Texas) of Ed. - 5:No.9:43-48 (Oct. 1929)

21. Gerry, Henry L. - - - - "Some of the Factors Determining the Common Content of High School Chemistry"
Sch. Sci. Math. - 24:457-66 (May 1924)

22. Gorden, N. E. - - - - - "The Teaching of Chemistry in the High Schools"
Sch. & Soc. - 26:264 (Aug. 27, 1927) No.661

23. Greer and Bennett - - - "Chemistry"
(Allyn and Bacon - 1926)

24. Guild, Bruce H. - - - - "The Need for a More Socialized Emphasis on Chemistry as Taught in High School"
Sch. Sci. Math. - 31:1075-78 (Dec. 1931)

25. Harrow, Benj. - - - - - "The Making of Chemistry"
(John Day Co. 1930)

26. Hessler, John C. - - - "The Correlation of High School Chemistry and Daily Life"
Sch. Sci, Math. - 12:290-95 (Apr. 1912)

27. Howe and Turner - - - - "Chemistry and the Home"
(C. Scribner Sons - 1927)

28. Hunter, George W. - - - "Science Teaching"
American Book Company - 1934

29. Jones, Mary E. - - - - -"A Chemical Course for Girls"
N.E.Ass. Proc. - 1915:1019-20

30. Lake, Charles H. - - - -"Looking Ahead in Science Teaching"
Sch.Sci.Math. - 34:136-43 (Feb. 1934)

31. Lamont, B. F. - - - - - "Grade School Methods an Asset to the Chemistry Teacher"
J.of Chem. Ed. - 7:2701-03 (Nov. 1930)

32. Le Vesconte, Amy - - - -"Adapting Elementary Chemistry to Girls' Interest"
J.of Chem. Ed. - 9:1620-24 (Sept. 1932)

33. Lewis, E. P. - - - - - -"The Place of Pure Science in our Public School System"
N.E.Ass. Proc. - 1915:1024

33A.Literary Digest - - - - 118:15 (August 11, 1934)

34. Newell, L. C. - - - - - "A Brief Course in Chemistry"
(D. C. Heath & Co. 1929)

35. Osborne, C. E. - - - - -"New Life in Old Chemistry"
J.of Chem. Ed. - 2:346-353 (May 1925)

36. Osborne, Raymond W. - - "Modernizing our Secondary School Science"
Sch. Sci. Math. - 31:608-9 (May 1931)

37. Phelps - - - - - - - - - See Stieglitz (50)

38. Powers, S. R. - - - - - "Objectives of High School Chemistry"
Sch. Sci. Math. - 25:832-833 (Nov. 1925)

39. Sampey, John R. - - - - "A New Responsibility in Chemical Education"
Sch. Sci. Math. - 29:615-22 (June 1929)

40. Sampson, J. S. - - - - -"A course in Chemistry Derived from Problems in Industry"
B. U. Thesis (1933)

41. Segerblom, Wilhelm - - -"Changing Trends in Teaching Chemistry"
Sch. Sci. Math. - 34:524-25 (May 1934)

42. Sheean, J. Lyman - - - -"Application of Psychology to the Teaching of High School Chemistry"
J.of Chem. Ed. - 6:2181-88 (Dec. 1929)

43. Sherman, Henry C. - - - "Chemistry of Food and Nutrition"
(Macmillan Co. - 1927)

44. Sherman, Henry C. - - - "Food Products"
(Macmillan Co. - 1933)

45. Smith, Alexander - - - -"The Teaching of Chemistry"
(Longmans, Green and Company (1902)

46. Smith, H. O. - - - - - - -"The Teaching of Science"
Bulletin of the State Dept. of Education(Texas)
7:134-80 (Sept. 1931)

47. Snedden, David - - - - - -"Two Types of Chemistry in High Schools"
School Review - 29:646-48 (Nov. 1921)

48. Sohon, Michael D. - - - "Chemistry in Secondary Schools"
Science 31:979-983 (June 1910)

49. Statistical Abstracts of the United States - 1933

50. Stieglitz, Julius - - - "Chemistry in Medicine"
(The Chemical Foundation - 1928)

51. Stone, Charles H. - - - "A New High School Course in Chemistry"
J.of Chem. Ed. - 1:233-239 (Dec. 1924)

52. Superintendent's Bulletin No.42 - Oakland Public Schools -
"Chemistry for High Schools"
Course of Study Series - (1922)

53. Thatcher, R. W. - - - - See Chamberlain (10)

54. The New International Encyclopaedia - (Dodd, Mead & Co. (1930)

55. The World Almanac - - - 1932 (N.Y.World Telegram)

56. The World Almanac - - - 1933 " " "

57. The World Almanac - - - 1935 " " "

58. Thorp, Frank H. - - - - "Outlines of Industrial Chemistry"
(3rd revised and enlarged edition -
Macmillan Co. 1925)

59. Twiss, G. R. - - - - - - -"A Textbook in the Principles of Science Teaching"
(Macmillan Co. 1917)

60. U. S. Bureau of Education - "Science Teaching in Secondary Schools in the War Emergency"
Bulletin 1918 - Secondary School Circular No. 3

61. U. S. Bureau of Education - "Reorganization of Science in the Secondary Schools"
Bulletin 1920--No. 26

62. U. S. Dept. of Agriculture - Dept. Bulletin No. 103

63. Van Buskirk & Smith -- "The Science of Everyday Life"
(Houghton Mifflin - 1933)

64. Wirich, C. M. - - - - "Chemistry Adapted to Social Needs"
Sch. Sci. Math. - 21:142-143 (Feb. 1921)

65. Woodhull, John F. - - "Modern Trend of Physics and Chemistry Teaching"
Ed. Rev. - 31:236-47 (March 1906)

66. Fourteenth Census of the U. S. Taken in the Year 1920- Bureau of the Census (Dept. of Commerce)

67. U. S. Tariff Commission -"Census of Dyes and Coal-tar Chemicals" 1917
(Government Printing Office - Washington)